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Influence of Weather Elements on Phenological Stages and Yield Components of Tomato Varieties in Rainforest Ecological Zone, Nigeria

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Abstract
Production of tomato (*Lycopersicon esculentum*) is severely affected during the peak of rainy seasons in South-western Nigeria leading to a decline in yield and fluctuation of prices. To study and identify the impacts of climate variability on phenological stages and yield components of tomato, tomato was cultivated in two separate peak rainy seasons (August to October, 2009 and May to July, 2010) in the Federal University of Technology Research Farm, Akure, Ondo State, South-west Nigeria. Climatic variables including rainfall (RR), relative humidity(R/H), maximum temperature (T_max), minimum temperature(T_min) were evaluated on four different tomato varieties (Roma VFN, Ibadan Local, Beske, UTC) with respect to tomato growth stages and quality of its yield components. The results showed that Ibadan local and Beske varieties started flowering exactly 6 Week After Transplanting (WAT) earlier than other varieties as well as varied in yield components. As seen from both planting seasons, Ibadan local (Ib.local) and Beske varieties produced significantly higher number of fruits/plant and fresh weight of fruits/plant than other varieties under the prevailing climate condition. The results show positive effects of rainfall during vegetative growth and negative effects during reproductive growth. Also, strong negative associations were observed between the yields and relative humidity. The correlations between rainfall and mean temperature with a yield of different tomato varieties were not consistent in both sign and magnitude. Fruit weight of the varieties was negatively correlated with RR, R/H and T_min with exception of Beske variety that was positively correlated with rainfall in the second planting season. In general, at significant level ($\alpha \leq 0.05$), second planting (May-July) is more favourable by prevailing climatic condition compared to first planting (August- October) with respect to yield quantity and quality obtained.
Key word: phenological development, climatic variables and tomato varieties.

1. Introduction

Tomato (Lycopersicon esculentum Mill.) belongs to the family of Solanaceae and is one of the most popular and nutritious vegetable crop after potato but top the lists of canned vegetables. Tomato is grown in all ecological zones of Nigeria with an average yield of 5-7t ha-1 recorded in the rainforest ecological zone of the south and up to 10 t ha-1 reported for savanna ecological zones of the north (Anon, 1989). It is a very cheap source of vitamins, essential in the metabolic activities of man (Bodunde, 1999). The world average productivity of tomato is around 22t ha-1 (FAO, 2008). Its total production in Nigeria varied between 889,000 and 898,000 tones between year 2004 and 2007 (FAO, 2008; Kabura, 2009). In Nigeria, tomato (Lycopersicum esculentum) yields output when compared with the average yield of 13.5 t ha-1 for other tropical Africa and the world average of 22 t ha-1. In the meantime, the shortage in the months of peak rainfall (May – November) and a production glut in the months of harvesting (March to May and September to October) lead to dichotomy in the distribution of annual tomato production across all agroecological zones

Tomato production in the rainforest ecological zone is relatively low compared to its level of utilization and consumption than any other part of the country (Bodunde, 1999). Production of the crop in this agroecological zone (rainforest) had been limited majorly by climatic factors, which includes temperature, humidity and high rainfall (Agele et al., 2002). During the months of March through June, little production takes place in the savannah ecological zones due to high temperature. Increasing day and night temperatures which are common phenomena exert their toll on tomato by reducing flowering, fruit-set and yield (AVRDC 2002). Phenological development governs the plant growth and productivity (Awal and Ikeda, 2003b). Days to flowering, fruiting and maturity of the crop are the important phenological events which determine the productivity of the crop. Temperature plays a major role in phenological development and productivity of crop plants. High temperature influences crop to mature. Report also shows that the production level is relatively affected in the rainforest zone by high amount of rainfall and unevenly distribution rainfall during the rainy season (Adekiya and Agbede, 2009; Ewulo et al., 2008). The heavy tropical rains experienced in this region cause mechanical damage, especially to flowers, coupled with high humidity that create a friendly environment for pests and diseases results in poor quality of its fruit and low yield (Ahmad and Singh, 2005). The effect of rainfall, however, may differ depending on its characteristics (drop size, intensity and duration) and the crop growth stage involved. Therefore, this study was conducted to determine the influence of weather elements on phenological stages and yield component of different tomato varieties in rainforest ecological zone, Nigeria, and to determine favourable planting season for the varieties used during the rainy season.

2. Data and methods of analysis

This study was carried out at the Research Farm of the Federal University of Technology, Akure, Ondo State, Nigeria (lat 7.170N, long 5.80 E) between the year 2009 and 2010 growing season. The experimental farm is located in a tropical rainforest zone of South-west, Nigeria. The climate of the area was characterized by heavy rainfall during the months of May to July and August to October. The soil of the site is sandy loam that is also classified as clay skeletal oxicpaleustalf (USDA taxonomy). The nutrient status of surface soil (0 - 15cm) at the experimental site before planting was found to comprise of N (0.19 mg/kg); P (7.69mg/kg); K, Ca and Mg (1.75, 0.84, 4.39 cmol/kg soil respectively) and with a pH of 6.8, organic matter (2.42 g/kg), bulk density (1.28 Mg/m3) and water holding capacity (0.061 g/g). The field preparation was performed manually. Four tomato varieties that were planted included Ibadan local (Ib. local), UTC, Roma VFN and Beske. These varieties were obtained from NIHORT, Ibadan, Nigeria and were experimentally evaluated from the month of August to October, 2009. The experimental design used was the Randomized Complete Block Design (RCBD) with three replications. The experimental unit plot size was 2mx2m.The tomato seedlings were raised in a well pulverized rich loamy soil and were transplanted into the field after 28days after seed planting at a distance of 0.4x0.75m. Measurement was taken on a weekly basis until maturity. The crop growth recorded includes of plant height (cm), number of leaves per plant, leaf area per plant (cm2), dry weight of leaves and fruits per plant (g), number of flower clusters per plant, number of fruits per cluster, number of fruits per plant, weight of individual fruit (g), weight of fruits per plant (kg), weight of fruits per plot (kg) and fruit yield (t/ha). Tomato yield was measured at the final harvest. A repeat of the experiment was carried out during the first of peak of the rainy season in the year 2010 (May-July). Weather data including rainfall (RR), maximum temperature (T_max), minimum temperature (T_min) and relative humidity(R/H) were simultaneously measured on a weekly basis in both planting seasons. Data were analyzed to establish a relationship between various growth stages and weather elements considered using the bi-variate correlation method and Analysis of variance (ANOVA) that were adjudged by the Least Significant Difference (LSD).

3. Results and discussions

3.1 Tomato phenological development

The tomato plants growth patterns shows an initial slow growth in the nursery and the accelerated or exponential growth as observed in the field after the normal slow establishment of the plant after transplanting. This observation agreed with Olaniyi and Fagbayide, 1999) who found that the plant showed slowly growth in height at the beginning, increasing to a maximum then slow down again so that the graph obtained by plotting height against time is like an oblique‘S’ in shape. However, fig.1a&b show seasonal growth and development of tomato plants with different varieties respectively. These figures show that plant height , number of branches per tomato plant, plant leaf area index (LAI) and percentage flowering steadily increased with season, all the varieties attained their maxima at 10.5 Week After Transplanting (WAT). There was a significant variation on these parameters, the tallest plants, maximum number of branches/plant, higher leaf area expansion rate and LAI were common in the Ibadan local and Beske compared to Roma VFN and UTC varieties which indicate genotypic differences. Irrespective of the climatic effects especially heavy rainfall at the site, Ibadan local (Ib. local) and Beske exhibited better performances (in both seasons) and more tolerant to adverse weather condition compared to Roma VFN and UTC varieties. Table 1 shows the percentage flowering of the tomato varieties studied over time after transplanting. Ibadan local presented early to flowering and first maturity by about 6 and 10 weeks after transplanting (WAT) respectively, earlier than the other varieties planted**.** As seen in this table**,** this variety also attained maximum percentage flowering earlier than the rest of the varieties.

Table 1: Percentage flowering of Tomato varieties

Varieties	Wk 6	Wk 7	Wk 8	Wk 9	Wk 10	Wk 11	Wk 12	Wk 13
Ib local	5	28	60	65	76	100	100	100
Beske	3	28	48	61	80	98	100	100
UTC	0	15	30	53	64	86	100	100
Roma VFN	0	18	36	58	70	91	100	100

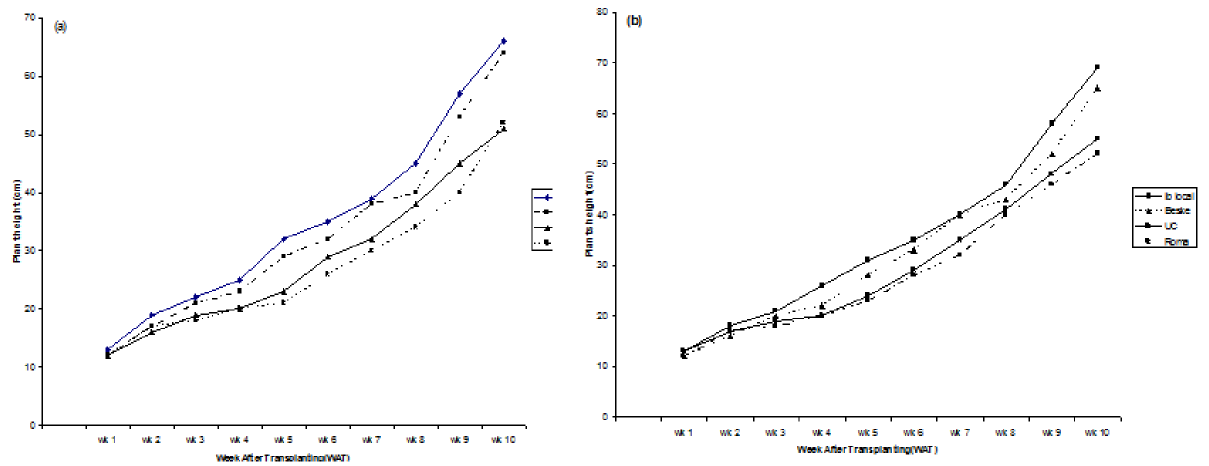

Fig.1a&b: Seasonal growth and development of tomato plants with different varieties in Aug.-Oct., 2009 and May to Jul., 2010 planting season

3.2 Tomato yield and yield components for different varieties

The number of fruits, fruit weight per plant and total fruit yield per hectares of tomato varieties used is presented on Table 2. The fruit yield per plant and total fruit yield were statistically significant among the varieties. The highest values were recorded from Ibadan local (Ib. local) while Roma VFN gave the least values. The low marketable yield was obtained this might be due to non-development of flowers into fruits as about 50% of the flowers developed into fruits and fruit cracking in some varieties. This result was in agreement with Weerakkody and Peiris, (1997) who found that under heavy rainfall and low temperature during flowering and fruit growth could result into low production of tomato in humid tropics. As observed from both planting seasons, Ibadan local (Ib. local) and Beske varieties produced significantly greater number of fruits/plant and fresh weight of fruits/plant than other varieties under the prevailed climate conditions. The varietals differences in growth and yield might be attributed to the differences in ecological distribution of the tomato varieties (Olaniyi, 2007). The variation in yield may also be due to genetic differences among the varieties since they were grown under the same environ-mental conditions (Olaniyi and Fagbayide, 1999). The low yield recorded in this study compared with that of the temperate region is in conformity with the finding of Adelana (1978), who reported about 5 and 20 tons per hectare as the average yield in the main tomato growing areas of Southern and Northern Nigeria, respectively.

Table 2. Yield components of the tomato varieties for both seasons

Yield component	**First Planting(Aug.,-Oct.,2009)**				**Second Planting(May-July,2010)**			
	Roma VFN	UTC	Ib local	Beske	Roma VFN	UTC	Ib local	Beske
Number of fruit/plant	4.8	5.3	8.4	6	6.3	5.5	7.8	10.3
Fruit weight /plant(gram)	70.3	60.7	100.5	90.8	75.6	81.3	165.5	115
Fruit yield (kg/ ha)	2364.5	2041.6	3380.7	3054.0	2542.7	2734.4	5566.4	3867.9

3.3Climate impacts on tomato growth and development

Figures 2a&b show rainfall distribution during the different growth stages of tomato in both year planting seasons (2009 and 2010) respectively. The high rainfall trend was observed during vegetative growth, followed by the flowering and fruit growth stages. Table 3a shows the bi-variate correlation coefficients between climatic variables and vegetative growth to flowering stages (1-10WAT). There was low correlation coefficients in the first growing season (August- October) in the year 2009, but a stronger relationship was observed during second growing season (May –July) in the year 2010 and statistically significant at $*\alpha \leq 0.05$. It may be as a result of low weekly rainfall pattern in this period compared to more heavy rainfall experienced in the first planting season (August- October). Also, Table 3b shows bi-variate correlation coefficient between climatic elements and tomato percentage flowering (6-13WAT) at significant level $*\alpha \leq 0.05$. The tomato varieties were positively correlated with rainfall while flowering (6-13WAT) in the second planting season (May-July) implying that the frequency of rainfall is beneficial and crucial during flowering/fruit growth as it enhances pollination of the flowers (Parker *et* al., 1995).The effect of the first planting season (August –October) was in the opposite that shows that all the varieties were negatively correlated with rainfall. It implies that heavy rainfall during flowering may have led to the drop-off, fruit dropping, and consequently, declined crop yields.

Table 3a: Bi-variate correlation coefficients between climatic elements and tomato plant height (1-10WAT) at significant level (*α ≤ 0.05) in both season (August- October, 2009 and May – July, 2010).

Climatic elements	First Planting				Second Planting			
	RomaVFN	*UTC*	*Ib local*	*Beske*	*RomaVFN*	*UTC*	*Ib local*	*Beske*
RR (mm)	0.03	0.05	0.17	0.13	-0.64*	-0.66*	-0.67*	-0.68*
R/H (%)	-0.14	-0.21	-0.25	-0.24	0.54*	0.53*	0.50*	0.51*
T_max(deg.C)	0.38	0.42	0.31	0.34	-0.68*	-0.67*	-0.57*	-0.58*
T_min(deg.C)	0.03	0.04	0.13	0.10	0.38	0.39	0.48*	0.46*

Table 3b: Bi-variate correlation coefficient between climatic elements and tomato percentage flowering (6-13WAT) at significant level (*α ≤ 0.05) in both season (August- October, 2009 and May – July, 2010).

Climatic elements	First Planting				Second Planting			
	RomaVFN	*UTC*	*Ib local*	*Beske*	*RomaVFN*	*UTC*	*Ib local*	*Beske*
RR (mm)	-0.02	0.01	-0.05	-0.10	0.46*	0.49*	0.41	0.41
R/H (%)	-0.45*	-0.40	-0.53*	-0.51*	0.52*	0.53*	0.58*	0.52*
T_max(deg.C)	0.35	0.37	0.37	0.30	-0.71*	-0.70*	-0.80*	-0.73*
T_min(deg.C)	0.34	0.33	0.32	0.38	-0.82*	-0.81*	-0.84*	-0.81*

As shown in table 3c below, fruit weight of the varieties was negatively correlated with RR, R/H and T_min with exception of the Beske tomato variety which was positively correlated with moderate strong correlation coefficient (0.52) with rainfall in second planting season. However, the fruit weight of Roma VFN and UTC gave rise to statistically significant (α ≤ 0.05), but negative correlation coefficients with rainfall during flowering and ripening stages. Based on the climatic pattern in both seasons, the results show that second planting (May-July) is more favourable to all the varieties used compared to first planting (August- October) in terms of yield quantity and quality obtained.

Table 3c: Bi-variate correlation coefficient between climatic elements and tomato yield (10-13WAT) at significant level (*α ≤ 0.05) in both season (August- October, 2009 and May – July, 2010).

Climatic elements	First Planting				Second Planting			
	RomaVFN	*UTC*	*Ib local*	*Beske*	*RomaVFN*	*UTC*	*Ib local*	*Beske*
RR (mm)	-0.55*	-0.61*	-0.10	-0.15	-0.41	-0.46*	-0.14	0.52*
R/H (%)	-0.89*	-0.80*	-0.90*	-0.80*	-0.17	0.68*	0.20	-0.87*
T_max(deg.C)	0.67*	0.65*	0.23	0.33	0.46*	-0.36	0.20	0.90*
T_min(deg.C)	-0.85*	-0.89*	-0.48*	-0.54*	-0.22	-0.63*	-0.28	0.61*

4. Conclusions

As deduced from the study, the variation in the rainfall distribution has created a determinant effect on the time of planting during different growth phases as affected yield components and fruit quality of tomato. The difference in yield, fruit number, fruit sizes and fruit weight emphasized the need for rain almost up to the stage of fruit maturity. Irrespective of the climatic pattern especially heavy rainfall at the site, Ibadan local (Ib.local) and Beske exhibited better performances (in both seasons) and more tolerant to adverse weather condition compared to Roma VFN and UTC variety in the region. Also, the frequency of rainfall pattern during flowering and fruit growth determine the production of the tomato yield as revealed from both seasons. At significant level (α ≤ 0.05), second planting (May-July) is more favourable by prevailing climatic condition compared to the first planting (August- October) in terms of yield quantity and quality obtained. Based on this study, the two leading varieties, (Ibadan local and Beske) are recommended to solve the problem of tomato scarcity during the peak of the rainy season in the zone. The result showed that Ibadan local and Beske varieties has more tolerant to any weather changes particularly rainfall and produced the greatest number marketable yield/plant while the field studied compared to Roma VFN and UTC. Also, the growing of tomato crop between May and July would produce greater marketable yield if it is well managed compared to the growing between August and October particularly for these varieties (Ibadan local and Beske) that was found to be tolerant with adverse weather condition.

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