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Yield performance and fruit characteristics of tomato (*Solanum lycopersicum* L.) genotypes in a high rainfall region

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Abstract

This study was to evaluate adaptation in vegetative, phenological and yield traits of five tomato genotypes (F1 hybrid Thorgal, NHTO 0294, NHTO 0201, B52 and Cameroun) to conditions in a high rainfall region at the Botanical Garden of the Plant Science and Biotechnology Department of Rivers State University, Port Harcourt, Rivers State, Nigeria. Seeds of five genotypes were nursed separately in plastic containers measuring 950cubic cm for seven weeks and transplanted into 55 x 45 x 45 cm polythene bags containing 10kg sandy-loam soil at one plant per bag. The bags were set out in a Completely Randomized Design in an open field with six replicates. Watering and weeding were carried out when necessary. Collected data were height of plant, number of leaves/plant, number of branches/plant, number of flower clusters/plant, days to 50% flowering, days to 50% fruiting, and days to 50% ripening/maturity. Others included quantity of fruits/plant, fruit length, fruit diameter, fruit weight, fruit shape index and overall fruit yield. The results showed that differences were significant (P=0.05) for number of branches, fruit weight, number of fruits/plant and fruit diameter with B52 having the highest number of 8 branches and 9 fruits/plant while Cameroun and F1 Thorgal had the least number of 2 branches each. Cameroun had the least number of one fruit/plant. The F1 hybrid Thorgal had the largest fruit diameter (4.4 cm) and highest fruit weight (66.9g). Other parameters studied (plant height, number of leaves, number of flower clusters, days to 50% flowering, fruiting, and maturity) did not differ significantly among tomato genotypes. The F1 Thorgal genotype is recommended for tomato production in Port Harcourt being well adapted and producing fruits almost three times bigger than fruits of other tomato genotypes.

Keywords: Tomato genotypes, adaptation, temperature, relative humidity, fruit characteristics, high rainfall region.

Introduction

The tomato plant (*Solanum lycopersicum* L.) is a globally valuable agricultural crop in the family *Solanaceae* and its much sought-after succulent fruit is the most notable vegetable grown worldwide after potato[1]. It is consumed garden-fresh in salads, sandwiches, and salsa and in processed state as soups, preservatives, juices, or pastes[1,2]. Moreover, it is found in numerous recipes and consumed in several meal preparations worldwide[3]. In the production of fresh-marketable tomato, it is crucial to balance the needs of farmers who are the producers, the marketers who are the sellers and those of consumers who are the end users. Critical to farmers are important traits like yield, fruit size, resistance to diseases and pests, tolerance to undesirable environmental variations such as cold, heat, relative humidity and rainfall, uniform/synchronous ripening, and harvesting that is mechanized[4-9]. For marketers, the main emphasis remains as half life that is long yet without being prone to spoilage, in addition to negligible injury during handling and haulage[3,10]. Whereas for consumers the important traits are fruit size, flavour, taste, appearance/colour and health benefits among others[11-13]. Among the least expensive and most sustainable methods for increasing tomato yield and expanding the land area under cultivation is the use of genotypes adapted to new locations and conditions, to environmental pressures and also resistant to diseases and pests. As a way to increase production, provide nutritious food to consumers, and improve smallholder farmers' incomes, it is imperative to have tomato varieties that combine environmental adaptation, yield potential, fruit quality, and resistance to pests and diseases. For meaningful crop improvement to be carried out, the first step is to make available sufficient genetic diversity, whose potentials for use in crop improvement are known and can be exploited [9]. Such genetic resources are useful to plant breeders only if they have been properly characterized and evaluated. These characterizations and evaluations enable plant breeders to investigate the genetic variability available within species in order to find genotypes that meet the requisite criteria to be used either as direct introductions into new environments outside their normal range of growth; or into habitats where they have not been grown before; or as new varieties to provide genetic diversity for hybridization with local varieties and selection of improved progenies in a breeding program. Yields of tomatoes in the high rainfall and humid forest regions in the coastal areas of Nigeria, is reported to be relatively low compared to the savannah region[14]. The four main factors responsible for the low yields in no particular order of severity are high rainfall intensity, high temperatures, high relative humidity and high disease and pest prevalence[15-17]. A significant association has been reported to exist between the amount and intensity of annual rainfall and the output of tomatoes[18]. A researcher, Guodaar[19] had stated earlier, that there is a significant statistically negative relationship between high rainfall and yield of tomato. This means that when rainfall intensifies, it reduces the yield of tomato, implying that although tomato requires water for growth and development, intense rainfall reduces its yield. Studies have shown that rainfall, relative humidity and temperature especially are critical to pollination, fertilization and fruiting in tomato. Optimum temperatures range between 21.1^0C–29.4^0C although daytime (morning) and night time temperatures are also critical. This is because, if temperatures rise above 32.2^0C before 10am in the morning, this will cause flowers to abort and make flower clusters to fall off. However, when temperature at night falls below 13.8^0C or goes higher than 23.9^0C, the result is damage to pollen grains whilst development of pollen tubes fails[20-22]. The period preceding flower an thesis especially from 8 to 13 days before, is a most crucial developmental phase for the tomato plant[23,24]. The factors that influence the optimum temperature for tomato include type of cultivar and its level of tolerance to varying temperatures, growth stage and developmental phase. Since the effects of high temperatures are varied and complex, average daily temperature of 29^0C throughout the 2-week period up to flower opening is designated the critical temperature for efficient and effective tomato development[25]. High temperatures had significant statistically negative relationship with tomato yield; meaning that increased temperature led to a substantial decline in yield of tomato when other variables like type of soil, use of agro-chemicals, applied irrigation, variety of tomato and routine weeding remained unchanged[19]. Generally, when temperatures are high, seedlings of tomato grow faster whilst differentiation and development of flowers is accelerated whereas percentage and rate of fruit set declines. Besides, high temperatures in the course of flowering leads to malformation and abscission of flowers, inadequate flowering, low-grade fruit quality, poor colour formation and sterility of pollen in tomato plants[26]. Moreover, substantial limitation in photosynthesis occurs as temperatures increase beyond the optimum level leading to remarkable losses in potential tomato yield[5]. Research into the correlation between mean daily temperatures and reproductive phase of tomato plants, noted that at 29°C daily mean temperatures, number of fruits, percentage of fruits set and weight of fruits per plant declined when compared to those at 25°C. The decrease in yield was attributed mostly to poor development of pollen and anther as well as reduced viability of pollen. Overall, susceptibility of tomato plants to temperatures above optimal at the reproductive phase can lead to a decrease in proportion of fruits set consequently lowering fruit yields of commercially cultivated tomato[27]. One other environmental factor that influences viability of pollen is relative humidity. When relative humidity rises above 80%, tomato pollen becomes viscous and adhesive unable to let go of the anthers whereas when overextended periods, relative humidity drops below 60%, the pollen grains become too dry or the stigma too dry resulting in pollen failing to adhere and so cannot pollinate / fertilize[20,21,28]. A range of 50%–70% relative humidity is usually contemplated as optimal for pollination in tomato**.** Quality of pollen and fruit set of tomato increased at 60%–70% relative humidity and also improved pollination and fertilization compared to 30%–40% relative humidity. However, relative humidity of up to 90% increased susceptibility of pollen to heat stress[29,30]. Also low or insufficient light, high or low temperatures and rainy conditions often result in poor fertilization[21] leading to poor fruiting and ultimately low yields. Finally, tomato growers in Nigeria and West Africa have to deal with a variety of diseases and insects whose virulence become aggravated in the humid rainforest region. Numerous bacterial, viral, and fungal diseases limit the production of tomatoes. They include wilt diseases caused by bacteria, fusarium and verticillium, leaf spot, yellow leaf curl, late and early blight, septoria blight, etc. Other pests are nematodes, mining insects, fruit borers, thrips, and several species of aphids, mites and more recently the leaf miner of South American origin, *Tuta absoluta*[31-35]. Therefore, in most advanced economies, greenhouse-based cultivation of tomato has been adopted in order to minimize biotic and abiotic stresses and ensure an uninterrupted tomato supply throughout the year[36,37]. However, most subsistence and small holder farmers in many African countries cannot afford the prohibitive costs of greenhouse cultivation. Besides, tomato like other crops responds differently when subjected to numerous pressures and factors (biotic, abiotic and edaphic) encountered simultaneously in the field[7]. When In 2014, five fresh market tomato varieties (Op-B155, Shasta,Op-B149, Heinzand CRIP00) were introduced from the USA and the Crops Research Institute of Ghana (CRIG) and appraised for genetic variability and adaptability, plant and fruit attributes in Ghana, almost all the traits showed variability[38]. In Nigeria, the best area for cultivation of tomato is the agro-ecological Savannah zone, in which the weather and environmental conditions tend towards the ideal with fewer diseases and pests of tomatoes. Between latitudes 7.5ºN and 13ºN in Nigeria lie the main areas producing tomato, experiencing temperaturesrangingfrom 25ºC to 34ºC. Such areas are made up of states like Kano, Bauchi, Kaduna Plateau, Benue, Borno, Jigawain the north and Oyoand Delta in the south[39]. Port Harcourt in Rivers State, Nigeria, the location of this experiment (Latitude 4.847^oN & Longitude 6.975^oE), is characterized by comparatively high rainfall throughout the year averaging 2,500mm per annum with high temperatures (mean annual minimum and maximum temperatures are 25^0C and 28^0C respectively); high relative humidity all year round (minimum values of 80% and maximum of 89%), and solar radiation averaging 4hours daily. Scientists[40] declared that given the contrasting and diverse agro-ecological zones in Nigeria, and bearing in mind the differences in potential yield within various ecological zones, varietal trials of crops must be adopted and established across the country as a standard practice in plant breeding.

This study seeks to discover genotypes that are high yielding and which can adapt and are suitable for cultivation in the high rainfall and humid conditions of the rainforest prevalent in Port Harcourt, Rivers State, Nigeria. The information provided in this study, can be exploited in a tomato breeding program.

Materials and methods

Experimental Site: This research was carried out from September 2021 to March 2022 at the Botanical Garden of the Plant Science and Biotechnology Department of Rivers State University, Port Harcourt in Rivers State, Nigeria. The location of this experiment, Port Harcourt in Rivers State, is characterized by comparatively high rainfall throughout the year averaging 2500mm per annum with high temperatures (mean annual minimum and maximum temperatures are 25^0C and 28^0C respectively); high relative humidity all year round (minimum values of 80% and maximum of 89%), and solar radiation averaging 4hours daily.

Experimental Materials Seed Source and Sowing of Seeds: The five tomato genotypes used were sourced as shown in Table-1.

The seeds of five selected tomato genotypes were sown separately in sandy-loam soil contained imperforated plastic containers measuring 950cubic cm on the 24^{th} of September, 2021. The choice of planting time was predicated on the need to avoid the excessive rainfall typical of the peak rainfall periods between the months of May to July and September in the Port Harcourt area. Seven weeks after sowing (13^{th} of November, 2021), each seedling was transplanted into a 55x45x45cm perforated black polythene bag. The five tomato genotypes (treatments) planted in the polythene bags were each replicated six times and set out in a CRD (Completely Randomized Design) with a sample size of 30 plants in the open field. Watering, weeding and earthling of the plants were carried out when necessary. No pesticides, fertilizers or soil amendments were applied. Simple staking was done to prevent plants from lodging during fruiting.

Collection and Statistical Analysis of Data: The following data were collected: plant height, number of leaves/plant, number of branches/plant, days to 50% flowering, number of flower clusters, days to 50% fruiting, number of fruits/plant, days to 50% ripening/maturity, single fruit weight/plant. Single fruit weight was ascertained by weighing all fruits harvested from a plant and dividing by the total number of fruits harvested from same plant. A digital electronic compact scale (SF-400C3) was utilized in weight measurements. Other data were fruit length/fruit (cm) recorded by using a Vernier caliper (Columbus, Model-VCC) to measure at harvest from the stem end of the fruit to the blossom end and determining the mean; fruit diameter/fruit (cm) determined using Vernier caliper to measure diameter of harvested fruits at the largest diameter and the mean calculated; fruit shape index (FSI)**:** fruit shape index was assessed using the formula by Lokonga and Tonganga[41]**.**

$$FSI = \frac{\text{Fruit length}}{\text{Fruit diameter}}$$

Using this formula fruits were categorized into three:
Flat shaped Fruits: FSI < 0.8
Rounded/Spheroidal Fruits: FSI 0.80 = 1.20
Elongated/Ovoid shaped Fruits: FSI > 1.20

Yield of fruits per plant (kg)
=Number of Fruits per Plant x Weight of Single Fruit

Yield of fruits per hectare[42]

$$= \frac{\text{Yield of fruits per plant (kg) x } 10000m^2}{\text{spacing } (m^2) \text{ x } 1000}$$

All data collected were evaluated with the General Linear Model (GLM) of Statistical Analysis Software (SAS) SAS 2010 by ANOVA (Analysis of Variance) in a CRD (Completely Randomized Design) and tested for significance at 5% level of significance. Whenever the F test indicated differences were significant, treatment means were compared using Fisher's Least Significant Difference (LSD) at P=0.05. Pearson's simple linear correlation analysis (r) at $P = 0.05$ and $P = 0.01$ was performed to find out the relationships between the vegetative, phenological, yield components and yield of tomato.

Table-1: Tomato Genotypes utilized in the Evaluation Study in a High Rainfall Region, Port Harcourt, Rivers State, Nigeria.

Genotypes	Source
F1 hybrid Thorgal	Agriseed Ltd., Technisem – France
NHTO 0294	Genetic Resources Unit (GRU), NIHORT, Ibadan
NHTO 0201	Genetic Resources Unit (GRU), NIHORT, Ibadan
B52	Genetic Resources Unit (GRU), NIHORT, Ibadan
Cameroun	Local Market

NIHORT - National Institute of Horticultural Research and Training, Ibadan, Oyo State, Nigeria.

Results and discussion

Vegetative Responses of Tomato Genotypes: Plant Height: The height of tomato genotypes is shown in Figure-1. The differences in plant height among the five genotypes evaluated were not significant (P=0.05). However, B52 genotype was the tallest with a height of 61.0cm when compared to NHTO 0294 (54.8cm), F1 hybrid Thorgal (52.4cm), Cameroun (48.2cm) and NHTO 0201 (46.4cm). The tallest (B52) and shortest (NHTO 0201) plants were from the NIHORT station.

Number of Leaves: There was progressive increase in number of leaves as the tomato plants grew with NHTO 0294 having the highest number of leaves (43) at flowering while the F1 hybrid Thorgal had the least number of leaves (14) as shown in Figure-2. The three NIHORT genotypes, NHTO 0294 (43), NHTO 0201 (33) and B52 (38) had higher number of leaves than F1 hybrid Thorgal (14) and Cameroun (21). The differences observed in number of leaves of tomato genotypes were not significant (P=0.05).

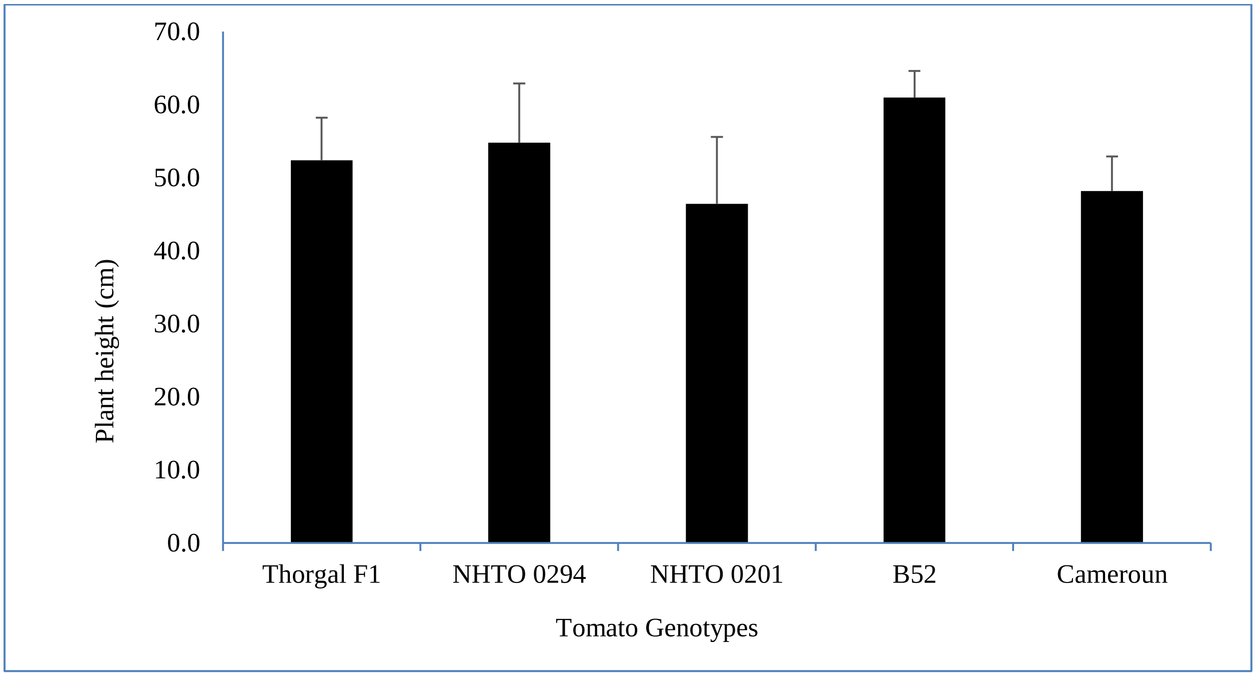

Figure-1: Plant height of five tomato genotypes in a high rainfall region, Port Harcourt, Nigeria.

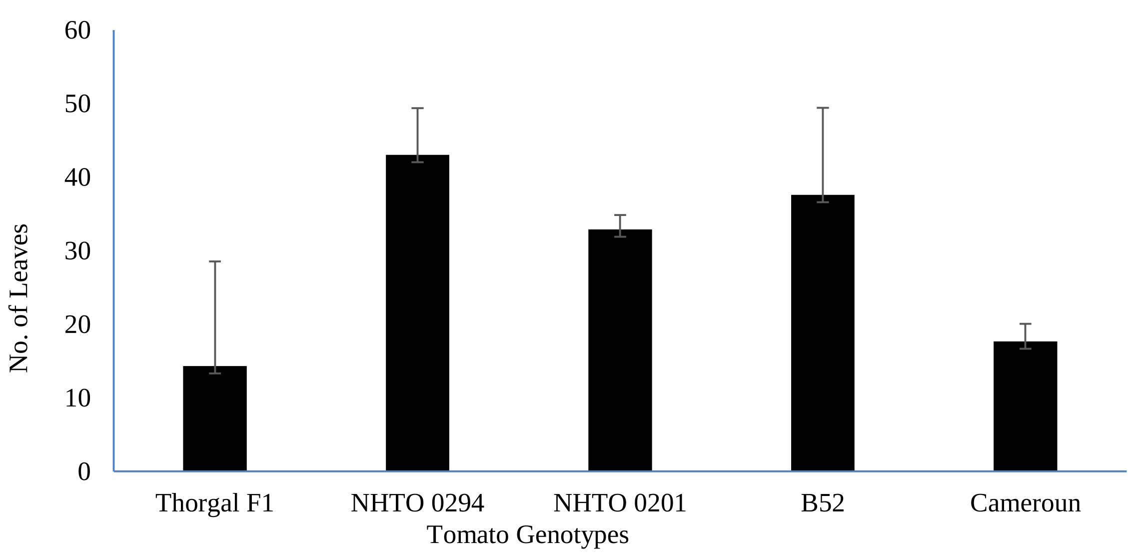

Figure-2: Number of leaves per plant of five tomato genotypes in a high rainfall region, Port Harcourt, Nigeria.

Number of branches per plant: In Figure-3, number of branches/ plant of the tomato genotypes is presented indicating that the differences found were significant (P=0.05). Number of branches (8) of genotype B52 was significantly higher (P=0.05) than all other genotypes. Also, differences in number of branches of NHTO 0294 (5) genotype and those of F1 hybrid Thorgal and Cameroun were significant (P=0.05), whereas number of branches of NHTO 0294 (5) did not differ significantly (P=0.05) from those of NHTO 0201 (4). The F1 hybrid Thorgal and Cameroun had the fewest number of branches per plant (2) which did not differ significantly (P=0.05) from that of NHTO 0201 (4). Again the 3 NIHORT, genotypes, NHTO 0294 (5), NHTO 0201 (4) and B52 (8) had higher number of branches than the F1 hybrid Thorgal(2) and Cameroun (2) genotypes.

Phenological Responses of Tomato Genotypes: The phenological responses (days to 50% flowering, days to 50% fruiting and days to 50% ripening/ fruit maturity) of the five tomato genotypes are shown in Table-2. The differences in the phenological characters of tomato genotypes were not significant (P=0.05). However, the NHTO 0294 genotype flowered at 77days after transplanting, which was earlier than other genotypes, whereas NHTO 0201 fruited at 90 days after transplanting which was earlier than other genotypes. The fruits of the B52 genotype matured at 119days after transplanting which was at least 7days earlier than other genotypes. Also, the three NIHORT genotypes (B52, NHTO 0294, and NHTO 0201) flowered, fruited and attained fruit maturity earlier than the F1 hybrid Thorgal and the Cameroun genotype.

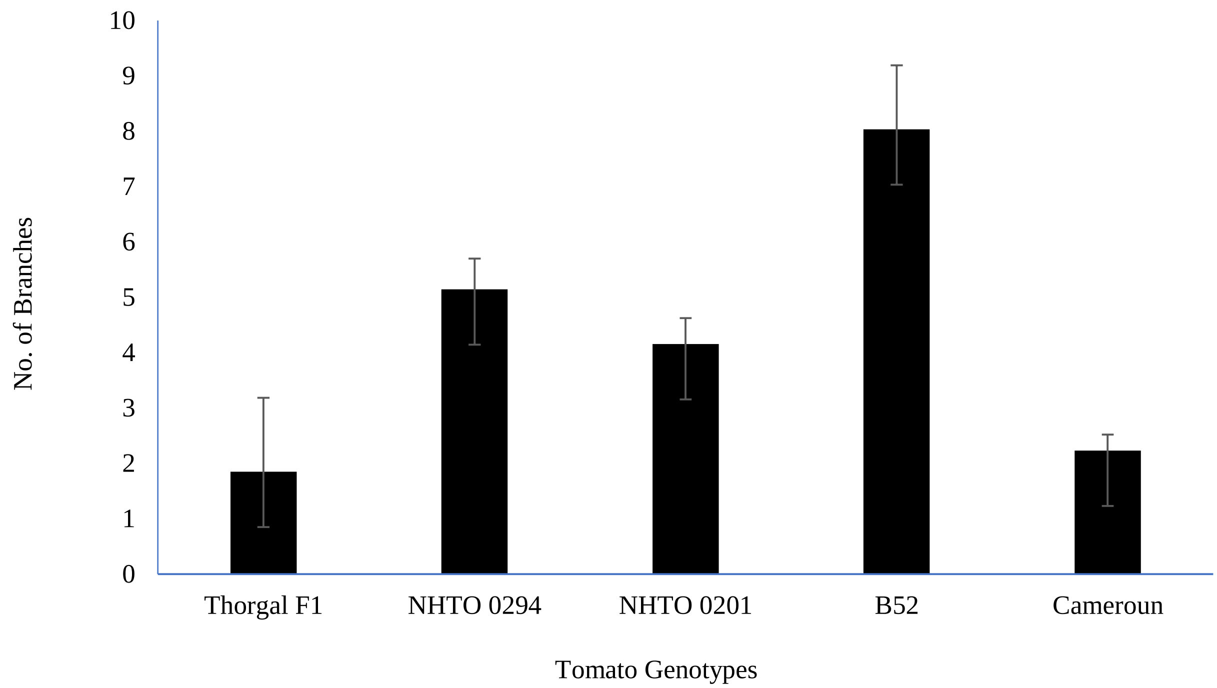

Figure-3: Number of branches per plant of five tomato genotypes in a high rainfall region, Port Harcourt, Nigeria.

Table-2: Phonological Performances of Tomato Genotypes in a High Rainfall Region, Port Harcourt, Nigeria.

Genotype	Days to 50% flowering ± Standard Error	Days to 50% fruiting ± Standard Error	Days to 50% ripening/maturity ± Standard Error
Thorgal F1	85±1.9	98±3.4	129±4.2
NHTO 0294	77±2.4	93±3.4	126±6.3
NHTO 0201	78±4.0	90±2.4	127±4.9
B52	78±1.8	93±1.6	119±1.0
Cameroun	90±2.0	105±2.1	131±4.1

Flower and Fruit Characteristics of Tomato Genotypes: Number of Flower Clusters: The mean values for total flower clusters per plant are presented in Figure-4. The differences observed in flower cluster numbers per plant of tomato genotypes were not significant (P=0.05). The number of flower clusters (trusses/inflorescences) was highest in B52 (13) and least in the Cameroun (5) genotype. Again, the three NIHORT genotypes (B52, NHTO 0294, and NHTO 0201) had more flower clusters (13, 9, and 7 respectively) than the F1 hybrid Thorgal and Cameroun which had 6 and 5 respectively.

Yield, Yield Components and Fruit Characteristics of Tomato Genotypes: The responses in yield components and overall yield of the five tomato genotypes in a high rainfall region as recorded in the quantity of fruits per plant, quantity of seeds per fruit, fruit weight, fruit diameter, fruit length, fruit shape index and overall yield are provided in Table-3. Although the differences in the number of fruits per plant, single fruit weight and average fruit diameter among the five tomato genotypes were significant (P=0.05), the differences in the fruit length, fruit shape index, average number of seeds per fruit and overall yield were not significant (P=0.05). Genotype B52 had significantly the highest number of fruits per plant (9) than all other genotypes. This was followed by NHTO 0294 (7), which had significantly higher number of fruits than F1 hybrid Thorgal (2) and Cameroun (1) genotypes but not significantly higher than NHTO 0201 (4). The three NIHORT genotypes (B52, NHTO 0294, NHTO 0201) had more fruits (9, 7 and 4 respectively) per plant than the F1 hybrid Thorgal (2) and Cameroun (1) genotypes. However, the F1 hybrid Thorgal had significantly heavier fruit weight (66.9g) than the NIHORT genotypes B52 (20.0g), NHTO 0294 (18.0g), and NHTO 0201 (17.8g). Fruit weight of the F1 hybrid Thorgal was not significantly different from that of the Cameroun (43.1g), and the NIHORT genotypes with lower fruit weights did not significantly differ from the Cameroun genotype. Also, the F1 hybrid Thorgal had significantly larger fruit diameter (4.4cm) than genotypes B52 (2.5cm) and NHTO 0201 (2.5cm). Fruit diameter of the F1 hybrid Thorgal did not significantly differ from those of NHTO 0294 (2.8cm) and Cameroun (2.9cm). The NIHORT genotypes had the smallest fruit diameter. Although there were no significant differences in the length of fruit, fruit shape index, and quantity of seeds per fruit, the B52 had longer fruit length (6.0 cm) than NHTO 0294 (4.1), NHTO 0201 (5.0), F1 hybrid Thorgal (4.1), and Cameroun (4.9) genotypes. The F1 hybrid Thorgal genotype had spheroidal fruits with a fruit shape index of 0.95 while the other four genotypes (B52, NHTO 0294, NHTO 0201, and Cameroun) had ovoid shaped fruits with fruit shape indices of 2.39, 1.51, 1.97 and 1.84 respectively. Also, the NHTO 0201 genotype had more seeds per fruit (55) than the other genotypes (B52= 51, F1 Thorgal = 50, NHTO 0294 = 39 and Cameroun = 36). Fruit yield was not significant for all genotypes (Table-4). Genotype B52 which had significantly highest number of fruits had the highest yield of 3.58 ton/ha. This was followed by NHTO 0294 (2.73), F1 Thorgal (2.41), Cameroun (2.26), while NHTO 0201 (1.54) genotype had the lowest fruit yield.

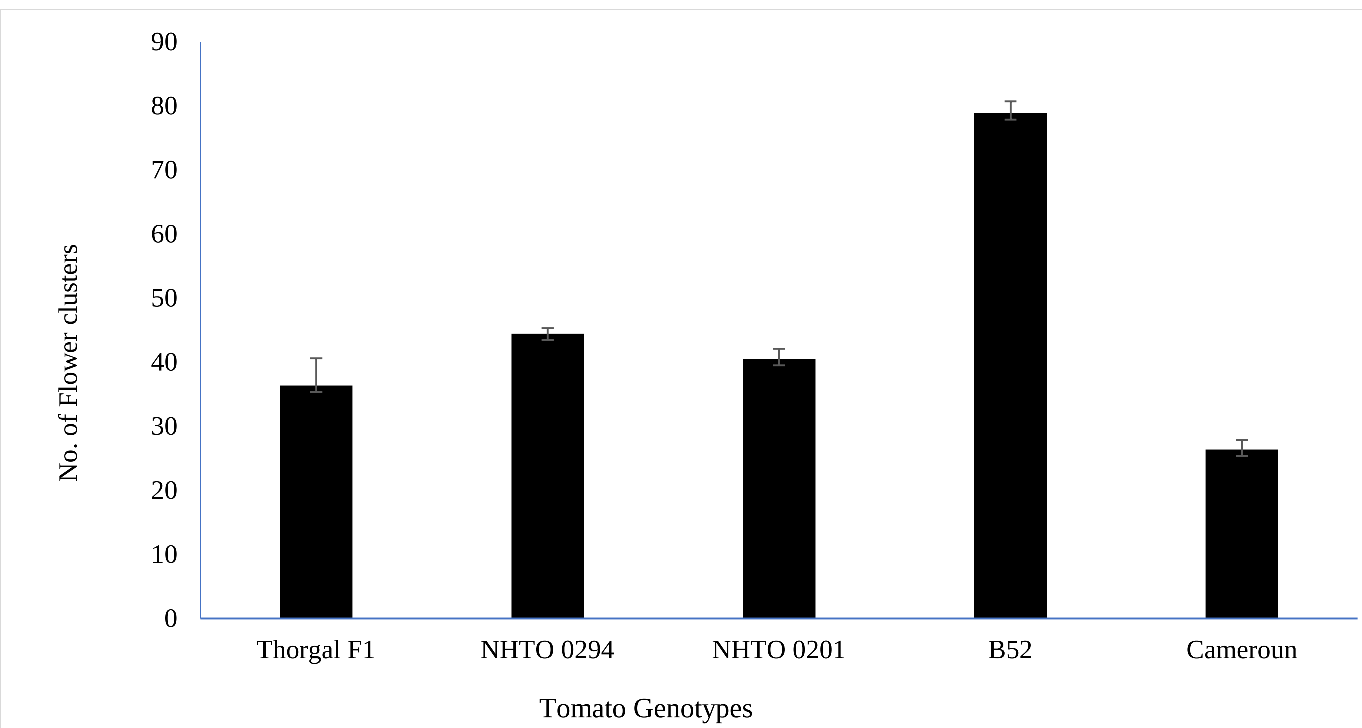

Figure-4: Variations in total flower clusters per plant of five tomato genotypes in a high rainfall region, Port Harcourt, Nigeria.

Correlations between Vegetative, Phenological and Yield Components: In Table-4, the correlation coefficients (r) matrix showing the relationship between the vegetative, phenological and yield traits in the five tomato genotypes are presented. There were no negative significant correlations. There were 18 significant positive correlations. All significant correlations indicate a positive relationship between 2 traits. There were 15 highly significant positive correlations All highly significant positive correlations indicate a highly positive relationship between 2 traits. Positive and highly significant correlations between any vegetative, phenological trait or yield component with the fruit yield of tomato is an indicator that selection for such a trait alone, or in combination with other traits showing same positive and highly significant correlations, can result in the production of high-yielding genotypes.

Table-3: Yield Components, Fruit Characteristics and Overall Yield of Tomato Genotypes in a High Rainfall Region, Port Harcourt, Rivers State, Nigeria.

Tomato Genotype	Number* of fruits per plant	Number of seeds per fruit	Fruit* weight (g)	Fruit* Diameter (cm)	Fruit Length (cm)	Fruit Shape Index	Overall Yield (ton/ha)
F1 Thorgal	2	50	66.9	4.4	4.1	0.95	2.41
NHTO 0294	7	39	18.0	2.8	4.1	1.51	2.73
NHTO 0201	4	55	17.8	2.5	5.0	1.97	1.54
B52	9	51	20.0	2.5	6.0	2.39	3.58
Cameroun	1	36	43.1	2.9	4.9	1.84	2.26
$LSD_{(0.05)}$	3.21	NS	29.71	1.89	NS	NS	NS

***Significant at *P* = 0.05, LSD = Least significant difference, NS = not significant.

Table-4: Simple LinearCorrelation Coefficient (r) Matrix showing the relationships between Vegetative, Phenological and Yield Components of Tomato Genotypes in a High Rainfall Region, Port Harcourt, Nigeria

	Yield	Plant height	No. of Leaves	No. of Branches	Days to 50% Flowering	No. of Flower Clusters	Days to 50% Fruiting	No. of Fruits	Days to 50% Fruit / Maturity	Fruit Weight
Plant height	0.951*									
No. of Leaves	0.908*	0.987**								
No. of Branches	0.914*	0.925*	0.878*							
Days to 50% Flowering	0.911*	0.991**	0.991**	0.876ns						
No. of Flower Clusters	0.963**	0.968**	0.927*	0.987**	0.928*					
Days to 50% Fruiting	0.911*	0.992**	0.991**	0.881*	1.000**	0.931*				
No. of Fruits	0.919*	0.885*	0.833ns	0.982**	0.818ns	0.969**	0.824ns			
Days to 50% Fruit Maturity	0.911*	0.992**	0.996**	0.882*	0.999**	0.932*	0.999**	0.824ns		
Fruit Weight	0.812ns	0.849ns	0.855ns	0.605ns	0.885*	0.720ns	0.881*	0.549ns	0.873ns	

****** = Highly Significant at 1%, ***** = Significant at 5%, ns = not significant.

Discussions: Vegetative Traits: Agronomic traits are effective indicators of crop variability that assist in selection of desirable parents in crop breeding programs. In such situations, the use of agronomic data makes it possible to conduct genotype variability and performance evaluation in the actual growing environment of a crop. Different genetic constitutions with regard to rate of growth and the suitability of the environmental conditions for each variety may be responsible for the variations in agronomic, phenological and yield components of tomato genotypes. Although plant height varied from 46.4 - 61.0 cm the differences in the heights of the tomato genotypes used in this study were not significant. However, the B52 genotype was the tallest (61.0 cm) whereas NHTO 0201 genotype was the shortest (46.4 cm) closely followed by the Cameroun genotype (48.2 cm), the F1 hybrid Thorgal (52.4 cm) and NHTO 0294 (54.8 cm). This would imply that despite the high rainfall and humidity with other weather conditions in Port Harcourt differences in the heights of tomato genotypes were not significant. Dunsin *et al*.[43] and Ketema and Beyene[44] also reported similar findings in the heights of tomato varieties in their separate studies. However, Dufera[45], Ugwuanyi *et al*.[46] and Sanjida *et al*.[47] found differences in height of tomato plants among genotypes they evaluated to be significant. The disparities in findings could be due to the genetic makeup of the tomato plants used in the various experiments and the field conditions under which they were cultivated. It could also be attributed to whether they were determinate or indeterminate in their growth habits. Also, differences in the number of leaves of the five tomato genotypes studied were not significant, although the three NIHORT genotypes, NHTO 0294, NHTO 0201 and B52 had higher number of leaves than the F1 hybrid Thorgal and Cameroun genotypes. This suggests that weather conditions in Port Harcourt did not significantly limit production of leaves. The differences could be due to the genetic make-up of the tomatoes with respect to leaf production. However, as the primary sites of photosynthetic activity, it is possible that the number of leaves produced could eventually impact the yield of the tomato genotypes. Other researchers Dunsin *et al*.[43] had pointed out that no significant differences were found in the number of leaves of tomato varieties they studied. However, some studies Chernet and Zibelo[48], Ugwuanyi *et al*.[46] and Sanjida *et al*.[47] declared that their research found significant differences in the number of leaves of tomato genotypes. The number of branches per plant was significantly different in the five tomato genotypes with the B2 genotype producing the most branches while F1 Thorgal and Cameroun genotypes produced the least number of branches. The three NIHORT genotypes, NHTO 0294, NHTO 0201 and B52 also had higher number of branches than the F1 hybrid Thorgal and Cameroun genotypes. Other investigations Chernet and Zibelo[48], Ugwuanyi *et al*.[46] and Sanjida *et al*.[47] had earlier confirmed differences in the number of branches in tomato varieties studied to be significant.

Phenological Responses: The phenological characteristics - days to 50% flowering, days to 50% fruiting, and days to 50% ripening/maturity did not differ significantly among the tomato genotypes. However, the genotypes from NIHORT (NHTO 0294, NHTO 0201, and B52) flowered within a day of each other (77, 78, 78 days from sowing respectively) and earlier than the other two genotypes F1 hybrid Thorgal and Cameroun which flowered 85 and 90 days from sowing respectively. In fact, the Cameroun genotype flowered, fruited and matured last of all the genotypes. Early flowering could be beneficial if it leads to early fruiting and early fruit maturity because it could allow for earliness to the market and higher prices for farmers, in addition to reducing exposure to diseases and pests that could cause serious yield losses to the crop in the field, otherwise there may not be any benefits arising from early flowering. Other studies Ismaeel *et al.*[49] and Sanjida *et al*.[47] had earlier stated that differences in days to flowering were not significant among tomato genotypes.

Yield and Yield-Components: The differences observed in number of flower cluster per plant in tomato might be associated with genetic influences of the varieties. Although number of flower clusters per plant did not significantly differ, the three NIHORT genotypes (B52, NHTO 0294 and NHTO 0201) had more flower clusters (13, 9 and 7 respectively) than the F1 hybrid Thorgal (6) and Cameroun (5) genotypes. This is different from the findings of Naz *et al*.[50] and Sanjida *et al*.[47] who declared that number of flower clusters differed significantly in the tomato varieties they studied. Among the five genotypes of tomato, number of fruits per plant differed significantly. Genotype B52 had significantly more fruits than the other four genotypes with the Cameroun genotype having the least number of fruits. Also, the NIHORT genotypes (B52, NHTO 0294 and NHTO 0201) produced more fruits per plant (9, 7, and 4 respectively) than the F1 hybrid Thorgal (6) and Cameroun (5) genotypes. The studies of Dufera[45], Sanjida *et al*.[47] and Ketema and Beyene[44] also showed that number of fruits per plant were significantly different for tomato genotypes in their experiments. Also the fruit width/diameter in the tomato genotypes studied differed significantly with the F1 hybrid Thorgal having wider fruits (4.4 cm) than other genotypes. However, this could be attributed to the genetic make-up of the plants in terms of the nature and size of fruits. Chernet and Zibelo[48], Ullah *et al*.[51], Ismaeel *et al*.[49], Sanjida *et al*.[47] and Ketema and Beyene[44], reported significant differences in tomato fruit diameter in different genotypes and indicated that this could be due more to their inherent genetic variability in terms of fruit diameter. Fruit weight of the tomato genotypes differed significantly. The F1 Thorgal had the heaviest fruits (66.9g) while the NIHORT genotypes (B52, NHTO 0294, NHTO 0201) possessed the lightest fruits (20.0g, 18.0g and 17.8g respectively) and the Cameroun genotype had fruits whose weights were intermediate (43.1g) of the F1 Thorgal and the NIHORT genotypes. This is in line with the reports of Ketema and Beyene[44] and Sora[52] who observed significant differences in the fruit weight of the tomato genotypes studied. Other scientists Baliyan and Rao[53] also found fruit weight of tomato genotypes assessed for disease and pest tolerance and production in Botswana to be significantly different among the tomato genotypes. An experiment by Chernet and Zibelo[48] showed significant differences among the four tomato genotypes tested. Although B52 had extra fruits per plant than the other genotypes, the fruits of B52 were small and may not attract maximum market value in Rivers State. The fruits of the F1 hybrid Thorgal were the biggest and had a greater market appeal than the other tomato genotypes tested. However, there is need to increase the productivity of the F1 hybrid Thorgal through soil amendments. Notably, Tao *et al*.[54] recorded a 43% increase in the yield of tomatoes when poultry manure was applied to tomato plants while Mfombep *et al*.[55] also observed an increase in the quantity of fruits per plant when tomato plants treated with poultry manure produced 30 fruits each compared to the untreated ones that produced 17 fruits.

Correlation Coefficients of Vegetative, Phenological and Yield Traits: Yield is a complex characteristic and is controlled by a large number of genes working together. Therefore, the effect of any one character on yield could be identified through correlation studies with a view to ascertaining the extent and nature of association existing among yield and yield attributing characters. The correlation coefficient (r) shows a positive correlation between yield and height of tomato plants, number of leaves, number of branches days to 50% flowering, number of flower clusters, days to 50% fruiting, number of fruits and days to 50% fruit ripening/maturity. These correlations between tomato traits were also observed by Wali and Kabura[56] and Mahapatra *et al.*[57]. The number of flower clusters correlated positively with days to 50% fruiting, number of fruits per plant and days to 50% fruit ripening/maturity. This suggests that, the more the quantity of flower clusters in a plant, the more fruits will be produced. Correlation result of quantity of flower clusters per plant with quantity of fruits per plant is in agreement with the conclusions of Monamodi *et al*.[58] who declared that these two components are positively correlated. The number of fruits did not correlate with the single fruit weight. The fruits of F1 Thorgal were of marketable value as they were the biggest in size and had more pulp compared to the other genotypes. Thus if selection pressure is directed towards the enhancement of any character that has a highly positive relationship with yield, it simultaneously affects several other similarly associated characters[59]; meaning that, knowledge of the relationship of characters with yield and with each other can provide strategies for making improvements through selection.

Conclusion

Adaptability of tomato genotypes to an environment can be estimated by observing the phenotypes of the plants and measuring the agronomic, phenological and yield and yield components. The variability in some attributes of tomato genotypes could be credited to differences in genetic constitution with respect to rate of growth and growth habit and appropriateness of the prevalent environmental growing conditions for the genotypes. The dearth of high-yielding tomato genotypes that are adapted to the high rainfall-characterized climate of Port Harcourt, Rivers State has been a constraint in the production and productivity of tomato. It is necessary to evaluate and identify tomato genotypes with high yield potential as the unpredictable performance of released varieties and hybrids cause low production of tomato when grown in unfavorable environments. Although the NIHORT tomato genotypes (B52, NHTO 0294, and NHTO 0201) were better adapted in terms of agronomic performance, phonological responses and quantity of fruits produced per plant, they had smaller fruits because of their genetic make-up. The F1 hybrid Thorgal had the biggest and widest fruits thus possessing the best market appeal of the tomato genotypes. From this study, the NIHORT tomato genotypes had more fruits per plant; however, the F1 hybrid Thorgal genotype had bigger fruits that were more than three times bigger than the fruits of the NIHORT genotypes thereby possessing a better market value/appeal. Therefore, the F1 hybrid Thorgal genotype is recommended for tomato production in Port Harcourt, Rivers State. A tomato breeding program to improve both yield of tomato and fruit quality should explore the possibility of cross breeding the NIHORT genotypes especially B52 with the F1 hybrid Thorgal. This may result in heterotic expression and substantial variability in subsequent segregating progeny population. Selection for higher fruit production and better fruit quality from the progenies could then be undertaken.

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References

1. Mujtaba, A. and Masud, T. (2014). Enhancing Post harvest storage life of tomato (*Lycopersiconesculentum* Mill.) Cv. Rio Grande Using Calcium Chloride. *American-Eurasian Journal of Agriculture Environment and Science*, 14(2), 143-149.

2. Pinheiro, J., Alegria, C., Abreu, M., Sol, M., Gonçalves, E. M., & Silva, C. L. (2015). Postharvest Quality of Refrigerated Tomato Fruit (S olanum lycopersicum, cv. Z inac) at Two Maturity Stages Following Heat Treatment. *Journal of Food Processing and Preservation*, 39(6), 697-709.

3. Beckles, D. M. (2012). Factors affecting the postharvest soluble solids and sugar content of tomato (Solanum lycopersicum L.) fruit. *Postharvest Biology and Technology*, 63(1), 129-140.

4. Wokoma, E. C. W. (2008). Preliminary Report on Diseases of Tomato in Choba, Rivers State. *Journal of Applied Sciences and Environmental Management*, 12(3), 117-121.

5. Bita, C. E., & Gerats, T. (2013). Plant tolerance to high temperature in a changing environment: scientific fundamentals and production of heat stress-tolerant crops. *Frontiers in plant science*, 4, 273.

6. Ajayi, A. M., & Hassan, G. F. (2019). Response of selected tomato (Solanum lycopersicum L.) cultivars to on-field biotic stress. *Journal of Agricultural and Crop Research*, 7(3), 38-46. doi: https://doi.org/10.33495/jacrn v7i3.19.110

7. Chaudhary, J., Khatri, P., Singla, P., Kumawat, S., Kumari, A., Vinaykumar, R., Vikram, A., Jindal, S. K., Kardile, H., Kumar, R., Sonah, H., and Deshmukh, R. (2019). Advances in Omics Approaches for Abiotic Stress Tolerance in Tomato. *Biology*, 8(90), 1-19. doi:10.3390/biology8040090

8. Onyia, V. N., Chukwudi, U. P., Ogwudu, V. C., Atugwu, A. I., Eze, S. C., Ene, C. O., & Umeh, S. (2019). Evaluation of Tomato Genotypes Growth, Yield, and Shelf Life Enhancement in Nigeria. Journal of Agricultural Science and Technology, 21(1), 143-152.

9. Ibitoye, D., Kolawole, A., & Feyisola, R. (2020, December). Assessment of wild tomato accessions for fruit yield, physicochemical and nutritional properties under a rain forest agro-ecology. *In Genetic Resources*, 1(2), 1-11.

10. Domínguez, I., Ferreres, F., del Riquelme, F. P., Font, R., & Gil, M. I. (2012). Influence of preharvest application of fungicides on the postharvest quality of tomato (Solanum lycopersicum L.). *Postharvest biology and technology*, 72, 1-10.

11. Martínez-Valverde, I., Periago, M. J., Provan, G., & Chesson, A. (2002). Phenolic compounds, lycopene and antioxidant activity in commercial varieties of tomato (Lycopersicum esculentum). *Journal of the Science of Food and Agriculture*, 82(3), 323-330.

12. Aoun, A. B., Lechiheb, B., Benyahya, L., & Ferchichi, A. (2013). Evaluation of fruit quality traits of traditional varieties of tomato (Solanum lycopersicum) grown in Tunisia. *African Journal of Food Science*, 7(10), 350-354.

13. Kanneh, S. M., Quee, D. D., Ngegba, P. M., & Musa, P. D. (2017). Evaluation of tomato (Solanum lycopersicum L.) genotypes for horticultural characteristics on the upland in Southern Sierra Leone. *Journal of Agricultural Science*, 9(6), 213-213.

14. Oladitan, T. O., & Oluwasemire, K. O. (2018). Influence of weather condition on selected tomato varieties in response to season of sowing in Akure, a rainforest zone of Nigeria. *Art Human Open Acc. J*, 2(6), 422-426.

15. Agele, S. O., Iremiren, G. O., & Ojeniyi, S. O. (2011). Evapotranspiration, Water Use Efficiency and Yield of Rainfed and Irrigated Tomato. *International Journal of Agriculture & Biology*, 13(4).

16. Bergougnoux, V. (2014). The history of tomato: from domestication to biopharming. *Biotechnology advances*, 32(1), 170-189.

17. Aniso, J., Hamadina, E. I., & Hamadina, M. K. (2015). Germination and Vegetative Growth of Selected Hybrid Tomato (Lycopersicum esculentum Mill.) Cultivars under Hot and Wet Environmental Conditions in Rivers State Nigeria. *Journal of Plant Sciences*, 3(2), 99-105.

18. Malyse, M. C. (2021). Rainfall variability and adaptation of tomatoes farmers in santa: northwest region of Cameroon. In African Handbook of Climate Change Adaptation. pp. 699-711. Cham: Springer International Publishing.

19. Ghana Guodaar, L. (2015). Effects of climate variability on tomato crop production in the Offinso North District of Ashanti region (Doctoral dissertation).

20. McCrea, S. (2005). Why blossoms of some vegetables fail to set fruit. Washington State Univ. Spokane County Ext. http://extension.wsu.edu/spokane/wp-content/uploads/ sites/33/2017/07/C148-Why-Blossoms-Fail-11.

21. Ozores-Hampton, M., Kiran, F., & McAvoy, G. (2012). Blossom Drop, Reduced Fruit Set, and Post-Pollination Disorders in Tomato. HS1195/HS1195, 7/2012. EDIS, 2012(7).

22. Whiting, D., O'Meara, C. and Wilson, C. (2012). Growing Tomatoes. Colorado State Univ. Ext. http://www.ext. colostate.edu/mg/gardennotes/717.pdf

23. Sato, S., Peet, M. M., & Thomas, J. F. (2002). Determining critical pre-and post-anthesis periods and physiological processes in Lycopersicon esculentum Mill. exposed to moderately elevated temperatures. Journal of Experimental Botany, 53(371), 1187-1195.

24. Sato, S., Kamiyama, M., Iwata, T., Makita, N., Furukawa, H., & Ikeda, H. (2006). Moderate increase of mean daily temperature adversely affects fruit set of Lycopersicon esculentum by disrupting specific physiological processes in male reproductive development. *Annals of botany*, 97(5), 731-738.

25. Biratu, W. (2018). Review on the effect of climate change on tomato (Solanum Lycopersicon) production in africa and mitigation strategies. *J Nat Sci Res*, 8(5), 2225-0921.

26. Johkan, M., Oda, M., Maruo, T., & Shinohara, Y. (2011). Crop production and global warming. Global warming impacts-case studies on the economy, human health, and on urban and natural environments, 139-152.

27. Giorno, F., Wolters-Arts, M., Mariani, C., & Rieu, I. (2013). Ensuring reproduction at high temperatures: the heat stress response during anther and pollen development. *Plants*, 2(3), 489-506.

28. Snyder, R. G. (1828). Greenhouse tomato handbook Mississippi State Univ. Ext. Serv. Publ.

29. Peet, M., Sato, S., Clément, C. and Pressman, E. (2002). Heat stress increases sensitivity of pollen, fruit and seed production in tomatoes (*Lycopersiconesculentum* Mill.) to non-optimal vapor pressure deficits. *Int. Hortic. Congr.: Environ. Stress Hortic. Crop.*,618, 209–215.

30. Huang, Y., Li, Y., & Wen, X. (2011). The effect of relative humidity on pollen vigor and fruit setting rate of greenhouse tomato under high temperature condition. *Acta Agric. Boreali-Occident. Sin*, 11, 1-20.

31. Subedi, N., Gilbertson, R. L., Osei, M. K., Cornelius, E., & Miller, S. A. (2014). First report of bacterial wilt caused by Ralstonia solanacearum in Ghana, West Africa. *Plant disease*, 98(6), 840-840.

32. Keatinge, J. D. H., Ledesma, D. R., Keatinge, F. J. D., & Hughes, J. A. (2014). Projecting annual air temperature changes to 2025 and beyond: implications for vegetable production worldwide. *The Journal of Agricultural Science*, 152(1), 38-57.

33. Osei, M. K., Bonsu, K. O., Agyeman, A., & Choi, H. S. (2014). Genetic diversity of tomato germplasm in Ghana using morphological characters.

34. Leke, W. (2015). Begomovirus disease complex: emerging threat to vegetable production systems of West and Central Africa. *Agriculture and Food Security*, 4(1), 1-14.

35. Ogunsola, E. (2021). Tomato production and associated stress: a case of African climate. *Single Cell Biology*, 10, 3.

36. Boulard, T., Raeppel, C., Brun, R., Lecompte, F., Hayer, F., Carmassi, G. and Gaillard, G. (2011). Environmental impact of greenhouse tomato production in France. *Agronomy for Sustainable Development*, 31(4), 757-777.

37. Viuda-Martos, M., Sanchez-Zapata, E., Sayas-Barberá, E., Sendra, E., Perez- Alvarez, J.A., andFernández-López, J. (2014). Tomato and tomato by products. Human health benefits of lycopene and its application to meat products: A review. *Critical Reviews in Food Science and Nutrition*, 54(8), 1032-1049.

38. Ochar, K. (2015). Studies on Genetic Variability in Agronomic and Fruit Quality Traits among Some Tomato (*Solanum lycopersicum*L.) Genotypes. University of Ghana**.**

39. Ugonna, C. U, Jolaoso, M. A. and Onwualu, A. P. (2015). Tomato Value Chain in Nigeria: Issues, Challenges and Strategies. *Journal of Scientific Research& Reports*, 7(7), 501-515.

40. Iken, J.E. and Anusa, A. (2004). Maize Research and Production in Nigeria. *African Journal of Biotechnology*, 3(6), 302-307.

41. Lokonga, O. and Tonganga, K. (2020). Influence of Decomposed Wood Sawdust on Growth and Yield of Foreign F1 (Thorgal and Mongal) Hybrid Varieties of Tomato (*Solanumlycopersicum* L.) Grown Under Kisangani Shelter (D.R Congo). *Scholars Bulletin*, 6(5), 105-122.

42. Alia, M. E., Karimb, M. R., Talukderc, F. U., & Rahmanc, M. S. (2020). Growth and yield responses of tomato (Lycopersicon esculentum Mill.) under different combinations of planting times and fertilizers. *Reviews in Food and Agriculture*, 1(2), 74-81.

43. Dunsin, O., Agbaje, G. O., Aboyeji, C. M., & Gbadamosi, A. A. (2016). Comparison of growth, yield and fruit quality performance of tomatoes varieties under controlled environment condition of the southern Guinea savannah. *American-Eurasian J. Agric. & Environ. Sci*., 16(10), 1662-1665.

44. Ketema, W., & Beyene, D. (2021). Adaptability study and evaluation of improved varieties of tomato (Lycopersicon esculentum L.) under irrigation for their yield and yield components in east Wollega, western Ethiopia. *Int. J. Adv. Res. Biol. Sci*, 8(7), 118-125.

45. Dufera, J. T. (2013). Evaluation of agronomic performance and lycopene variation in Tomato (Lycopersicon esculantum Mill.) genotypes in Mizan, southwestern Ethiopia. *World Applied Sciences Journal*, 27(11), 1450-1454.

46. Ugwuanyi, P. O., Nwankwo, O. G., Adinde, J. O., Anieke, U. J., Ukwuani, C. M., & Aniakor, A. C. (2016). Evaluation of performance diversity among four determinate tomato (Lycopersicon esculentum Mill.) varieties grown under high tunnel in iwollo, south eastern nigeria. *Int. J. Curr. Res. Biosci. Plant Biol*, 3(10), 49-56.

47. Sanjida, M., Howlader, J., Akon, M. R., & Ahmed, T. (2020). Effects of varieties and boron on growth and yield of summer tomato. *Asian J Crop*, 4(01), 141-149.

48. Shushay, C., & Haile, Z. (2014). Evaluation of Tomato varieties for fruit yield and yield components in western lowland of Tigray, Northern Ethiopia. *International Journal of agricultural research*, 9(5), 259-264.

49. Ismaeel, M., Khan, M. S., Shah, S. S., Ali, Z., Ali, A., Tawab, S. and Naeem, M. (2019). Assessment of different tomato genotypes for yield and morphological attributes. *Pure and Applied Biology*, 8(1), 295-303.

50. Naz, R. M. M., Muhammad, S., Hamid, A. and Bibi, F. (2012). Effect of boron on the flowering and fruiting of tomato. *Sarhad Journal of Agriculture*, 28(1), 37-40.

51. Ullah, M. Z., Hassan, L., Shahid, S. B. and Patwary, A. K. (2015). Variability and inter relationship studies in tomato (*Solanum lycopersicum* L.). *Journal of the Bangladesh Agricultural University*, 13(1), 65-69.

52. Sora, S. A. (2018). Review on Productivity of Released Tomato (*Solanum lycopersicum* L.) Varieties in Different Parts of Ethiopia. *Journal of Horticulture Science and Forestry*, 1, 102.

53. Baliyan, S. P. and Rao, M. S. (2013). Evaluation of Tomato Varieties for Pest and Disease Adaptation and Productivity in Botswana. *International Journal of Agricultural and Food Research*, 2(3), 20-29.

54. Tao, Y., Liu, T., Wu, J., Wu, Z., Liao, D., Shah, F. and Wu, W. (2022). Effect of Combined Application of Chicken Manure and Inorganic Nitrogen Fertilizer on Yield and Quality of Cherry Tomato. *Agronomy*, 12(7), 1574.

55. Mfombep, P. M., Fonge, B. A., Atembe-afac, A. and Tabot, P. T. (2016). Soil Type and Ammendment Influence Growth and Yield of Tomatoes *Lycopersicon esculentum* L. in the Humid Mt Cameroon Region. *International Journal of Current Research in Biosciences and Plant Biology*, 3(8), 58-64.

56. Wali, A. S. and Kabura, B. H. (2014). Correlation Studies in Tomato (*Solanum lycopersicum* L.) as Affected by Mulching and Cultivar during the Heat Period in the Semi-Arid Region of Nigeria. *International Letters of Natural Sciences*, 15, 1-7.

57. Mahapatra, A. S., Singh, A. K., Vani, V. M., Mishra, R. Kumar, H. and Rajkumar, B. V. (2013). Inter-relationship for Various Components and Path Coefficient Analysis in Tomato (*Lycopersicon esculentum* Mill). *International Journal of Current Microbiology and Applied Sciences*, 2(9), 147-152.

58. Monamodi, E. L., Lungu, D. M., & Fite, G. L. (2013). Analysis of fruit yield and its components in determinate tomato (Lycopersicon lycopersci) using correlation and path coefficient.

59. Singh, A. K., Solankey, S. S., Akhtar, S., Kumari, P., & Chaurasiya, J. (2018). Correlation and path coefficient analysis in Tomato (Solanum lycopersicum L.). *Int. J. Curr. Microbiol. App. Sci*, 7, 4278-85.