

Genotypic and Phenotypic Correlation between Fruit Yield and Its Components in Tomato under Different Nitrogen Supply

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Abstract

*Tomato (*Lycopersicon lycopersicum* (L.) (Karst) is one of the most commonly grown vegetables in Nigeria, where changes in climatic conditions, such as high temperature, rainfall and inappropriate Nitrogen (N) application do not allow realization of its potential yield. During the rainy season fruit set is very poor and little is known of specific optimum N fertilizer requirement. Understanding a single or combinations of yield components of top-quality tomato genotypes and specific N fertilizer requirement under hot rainy conditions is of significant important. To accomplish that experiment was conducted at Bayero University, Kano Research Farm and National Horticultural Research Institute, Bagauda sub-station Kano. Treatments consisted of three tomato varieties; Icrixina, Roma VF and UC82B and four levels of N fertilizer; 0, 50, 100, and 150 kg ha⁻¹. The treatments were laid out in randomized complete block design (RCBD) with three replications and factorially combined. Simple correlation analysis was done to assess the type of relationship among the genotypic vs phenotypic variables and fruit yield, regression analysis was carried out to determine the optimum level of N in the two locations. Result shows highly significant and positive correlation between fruit yield plant⁻¹ with aborted flowers, blossom end rot, cracked fruit, fruit per cluster, fruit per plant and fruit width in both locations. Days to 50% flowering and fruit length recorded most significant negative correlation indices with total yield plant⁻¹ and fruit yield per hectare. Differentially, aborted flowers shows positive correlation with blossom end rot in BUK but negatively correlated in Bagauda. The regression analysis carried out shows linear response at BUK and quadratic at Bagauda. Fruit yield increased in linear response to N rates application at Bagauda but seized reaches at 150 kg N ha⁻¹ at BUK. In conclusion, the present study revealed that early flowering and fruitfulness were the most crucial yield components for rainy-season tomatoes and N fertilizer level of 150kgN ha⁻¹ can be suggested for the optimum tomato production during the rainy season in the study area.*

Keywords: Correlation matrix; Icrixina; Kano; Nitrogen; Roma VF; Rainy Season; Tomato

1. Introduction

Tomato (*Lycopersicon lycopersicum*) is one of the most widely grown vegetables in Nigeria and efforts were being made to intensify its productivity by developing notable varieties. However, yield is a complex character; its direct improvement is difficult (Tiwari and Devendra 2011). Considering that the estimated population of Nigeria will be over 2200 million, and on an average the consumption of tomato in Nigeria is 10 grams per person per day (Olorunfemi and Ajibefun, 2007; World population prospects, 2019), the demand would be 2200 tons per day (FAO,

2019). Tomato production in Nigeria is mainly under field conditions, where changes in climatic conditions, especially high temperature and rainfall do not allow realization of economic yield (Zakari et al., 2016). There are fluctuations in the supply of tomatoes in the market, which leads to market glut (excess supply) during the on season and shortage during off-season, and dry season is the main production period with higher yields and area under cultivation (Zakari *et al.*, 2017). However, during the rainy season (June-September) fruit set is very poor probably due to high night temperatures, but the farmer's belief about the shortage during off-season is due to rainfall, but it was reported that high temperature and excessive humidity cause tomatoes to die off and stop setting fruits (David *et al.*, 2006). Under daytime temperatures higher than 31°C and night temperature above 22°C, tomatoes may fail to set fruit. (Bhattarai and Subedi, 1996a). Maximum day and minimum night temperature above 32°C and 21°C respectively are known to limit fruit set due to an impaired physiological process in flower and fruit setting and or abscission (Bhattarai and Subedi, 1996b). Consequently, there is a strong demand for hybrid and open-pollinated tomato cultivars that exhibit the desirable fruit characteristics found in both exotic and locally adapted varieties. These cultivars play a crucial role in improving rainy season tomato production, increasing consumer access to nutritious and high-quality tomatoes, promoting better health conditions, and boosting the income of small-scale farmers. The literature reveals little or no information on the individual traits or trait combinations that make excellent tomato genotype under hot-rainy conditions. Therefore, it becomes necessary to understand the single or combinations of yield components of top-quality tomato varieties under hot rainy conditions and come up with means of making tomato yield better. These could be achieved with the introduction of heat and rain tolerant varieties specifically for rainy season production.

Nitrogen (N) is one of the most important nutrients required for high tomato crop yields; as key component of enzymes, chlorophyll, vitamins, and other cell constituents, all of which are essential for crop growth and development. Several line of studies have demonstrated that N supply have positive effect on tomato quality and yield (Bènard et al., 2009; Zakari et al., 2017; Hernández, et al., 2020; Fan et al., 2022). However, other studies have reported that N supply rates had no significant effect on tomato yield and its variables but only improved the upper biomass (Zotarelli et al., 2009 Geisseler et al., 2019). Furthermore, crop response to nitrogen supply is generally very prompt, depending on the source, stage of plant growth, and environmental condition (Hernández, et al., 2020), in various regions, particularly in soils with low organic matter, nitrogen plays a dual role as the primary limiting factor for plant growth and crop yield. (Fillela *et al.*, 1995). Although tomato is an important crop in Nigeria, little is known of its specific Nitrogen fertilizer requirement during the rainy season. Current recommendation of N fertilizer for tomatoes in Nigeria was developed many years ago (Zakari *et al.*, 2016). Since then, many new tomato cultivars have been bred which have a higher yield potential and may also have higher fertilizer N requirements. Therefore, growers have a tendency to apply excess N fertilizer rather than risk under-fertilization and reduced yields. A better understanding of N fertilizer requirement of tomato is necessary to develop more sustainable production practices in Nigeria.

The specific objective of the study was to assess the degree of association between yield variables, fruit yield and different N supply rates, and its contribution toward yield in the two locations.

2. Materials and Methods

The experiment was conducted during 2014 rainy season, at Bayero University, Kano Research Farm (Latitude 11° 58'N and Longitude 8°25'E) and National Horticultural Research Institute, Bagauda sub-station Kano, (11°33'N and longitude 8°23'E). The treatments consisted of three tomato varieties (Icixina, Roma VF and UC82B) and four levels of N fertilizer (0, 50, 100, and 150 kg ha⁻¹). The treatments were laid out in randomized complete block design (RCBD) with three replications. The gross plot was 4 m x 4.5 m (18 m²) and consisted of six (6) ridges while the net plot size was 4 m x 1.5 m (6.0 m²) comprised of 2 inner rows. Seedlings raised in nurseries were transplanted to the field when the rainfall was fully established five weeks after sowing (5WAS), at a spacing of 75 cm x 50 cm, giving 48 plants per plot. missing stands were supplied within a week of transplanting. NPK 15:15:15 fertilizer was applied at 2 weeks after transplanting (WAT) to supply 30 kg each of N, P and K, the balance of nitrogen 20, 70 and 120 kg N ha⁻¹ was applied in form of Urea (46% N) at three (3) weeks after the first application.

Data was taken on five tagged plants leaving plants from the row after the border row to avoid the border effect; Days to 50% flowering, Number of flowers cluster⁻¹, fruiting clusters plant⁻¹, aborted flowers, Cracked Fruits, Fruit with Blossom End Rot, Fruits Cluster⁻¹

Number of Fruits Plant⁻¹:

$$\text{Number of fruits per plant} = \frac{\text{Number of fruits per net plot}}{\text{Number of plant stand per net plot}}$$

Mean Fruit Weight (g): Average fruit weight was measured using digital weighing scale (model: Soehnle-plateau, Capacity: 10kg/22 Ib) and computed by using following formula.

$$\text{Mean fruit weight} = \frac{\text{Total fruit weight from all the pickings}}{\text{Total number of fruits from all the pickings}}$$

Fruit length (cm): The length of twenty fruits per plot was measured from the base of the calyx to tip of the fruit using digital vernier caliper (Series-500 model) and the mean recorded.

Fruit width (cm): The diameter of twenty fruits per plot was measured using digital vernier caliper (Series-500 model) at the center (equatorial length) of the fruit and the mean recorded.

Total yield plant⁻¹ (kg): Total fruit weight of five plants was obtained from net plot using digital weighing scale (model: Soehnle-plateau, Capacity: 10kg/22 Ib) and the divided by five and the mean recorded.

Fruit yield ha⁻¹: The entire fruits from the net plots were harvested at successive intervals at maturity and weighed. Total fruit yield was determined by pooling the individual yields. These was converted into t ha⁻¹ and recorded.

$$\text{Yield hectare}^{-1} (\text{ton/ha}) = \frac{\text{Yield per net plot (kg)} \times 10,000}{\text{plot area (m}^2\text{)} \times 1,000}$$

2.1 Statistical Analysis

Simple correlation analysis was done to assess the type of relationship among the variables and fruit yield. Regression analysis was carried out to determine the optimum level of nitrogen in the two locations according to procedure of SAS (SAS Institute, 2001).

3. Results

The findings from Table 1 indicate a significant and positive correlation between fruit yield per hectare and various variables in BUK, including fruit yield per plant, aborted flowers, blossom end rot, cracked fruit, fruit width, fruit per cluster, and number of flowers. However, the variables "days to 50% flowering" and "fruit length" showed the most significant negative correlations with both total yield per plant and fruit yield per hectare. Furthermore, aborted flowers exhibited positive correlations with blossom end rot, fruit length, fruit yield per plant, fruit width, and fruit per cluster, while showing a negative correlation with "days to 50% flowering." Blossom end rot demonstrated a positive correlation with fruit yield per plant and fruit per cluster but had a negative correlation with cracked fruits.

In Table 2, the correlation matrix for variables and fruit yield in Bagauda revealed highly significant and positive correlations between total yield per plant and fruit yield per hectare. These variables were also positively correlated with aborted flowers, blossom end rot, cracked fruit, fruit per cluster, fruit per plant, fruit width, and fruit length, but negatively correlated with "50% days to flowering." Aborted flowers displayed negative correlations with blossom end rot, cracked fruit, and "50% days to flowering," but had positive correlations with fruit per cluster, fruit per plant, fruit width, and fruit length. Cracked fruit showed positive correlations with "50% days to flowering," fruit per cluster, fruit per plant, fruit width, and fruit length. Additionally, "50% days to flowering" exhibited highly significant negative correlations with fruit per cluster, fruit per plant, fruit width, and fruit length. Fruit width was positively correlated with fruit length.

The significant and positive correlations between fruit yield per hectare and several variables in both BUK and Bagauda have important implications for tomato production. These findings suggest that factors such as fruit yield per plant, aborted flowers, blossom end rot, cracked fruit, fruit width, fruit per cluster, and number of flowers can influence overall fruit yield. Moreover, the negative correlations observed with "days to 50% flowering" and "fruit length" indicate that early flowering and shorter fruit length may have a negative impact on total yield per plant and fruit yield per hectare. Additionally, the positive correlations between aborted flowers and blossom end rot, fruit length, fruit width, and fruit per cluster imply that managing and reducing flower abortion can potentially lead to improved fruit quality and yield. The positive correlations between blossom end rot and fruit yield components suggest that blossom end rot can have a negative impact on overall fruit yield. Furthermore, the positive correlations between cracked fruit and "50% days to flowering," fruit per cluster, fruit per plant, fruit width, and fruit length highlight the importance of managing fruit cracking to enhance yield.

The results revealed a noteworthy variation in the response of the tested tomato varieties to nitrogen (N) fertilization. In the Bagauda area, a strong positive correlation was observed between N rates and tomato yield, characterized by both linear and quadratic regression models (Figure 2 & 3). The linear regression exhibited a high coefficient of determination ($R^2=0.95$), indicating a significant relationship between increasing N rates and tomato yield. Additionally, the quadratic regression yielded an even stronger association ($R^2=0.97$), suggesting a curvilinear response with an optimal N rate for maximum yield. Conversely, at BUK, the relationship between N rates and tomato yield followed a linear positive trend (Figure 1), with a lower coefficient of determination ($R^2=0.72$) compared to Bagauda. This indicates that increasing N rates had a positive but slightly less pronounced impact on tomato yield in the BUK area compared to Bagauda. The difference between the locations in this study could be due to the variation in cultivar, soil type, temperature and precipitation during the growing season as indicated in supplementary Table 1 & 2.

Table 1: Genotypic and phenotypic correlation coefficient between fruit yield and its components in tomato at BUK

	Fruit Hectare ⁻¹	Yield Plant ⁻¹	Total Yield Plant ⁻¹	Aborted flower	Blossom end rot	Cracked fruits	Days to flowering	50%	Fruit length	Fruits plant ⁻¹	Fruits width	Fruits Cluster ⁻¹
Fruit Yield Hectare ⁻¹	-											
Total Yield Plant ⁻¹	0.999**	-										
Aborted flower	0.392*	0.392*		-								
Blossom end rot	0.292	0.292		0.482**	-							
Cracked fruits	0.171	0.171		-0.007	-0.097	-						
Days to 50% flowering	-0.509**	-0.509**		-0.335*	-0.132	0.104	-					
Fruit length	-0.039	-0.039		0.069	-0.158	0.284	0.281		-			
Fruits plant ⁻¹	0.889**	0.889**		0.394*	0.382*	-0.016	-0.666**		-0.232	-		
Fruits width	0.133	0.133		0.150	-0.011	-0.017	-0.122		0.637**	0.053	-	
Fruits Cluster ⁻¹	0.714**	0.714**		0.146	0.053	0.079	-0.687**		-0.194	0.776**	0.090	-

*= significant at 5%

**= significant at 1%

Table 2: Genotypic and phenotypic correlation coefficient between fruit yield and its components in tomato at Bagauda

	Fruit Yield Hectare ⁻¹	Yield Plant ⁻¹	Total Yield Plant ⁻¹	Aborted flower	Blossom end rot	Cracked fruits	Days to 50% flowering	Fruit length	Fruits plant ⁻¹	Fruits width	Fruits Cluster ⁻¹
Fruit Yield Hectare ⁻¹	-										
Total Yield Plant ⁻¹	0.999**	-									
Aborted flower	0.091	0.091	-								
Blossom end rot	0.102	0.102	-0.136	-							
Cracked fruits	0.228	0.228	-0.148	-0.056	-						
Days to 50% flowering	-0.330*	-0.330*	-0.237	0.005	0.066	-					
Fruit length	0.552**	0.552**	0.029	0.045	0.083	-0.703**	-				
Fruits plant ⁻¹	0.885**	0.885**	0.087	0.092	0.171	-0.517**	0.728**	-			
Fruits width	0.516**	0.516**	0.261	0.098	0.104	-0.037	0.040	0.307	-		
Fruits Cluster ⁻¹	0.511**	0.511**	0.078	-0.025	0.051	0.259	-0.073	0.200	0.773**	-	

*= significant at 5%

**= significant at 1%

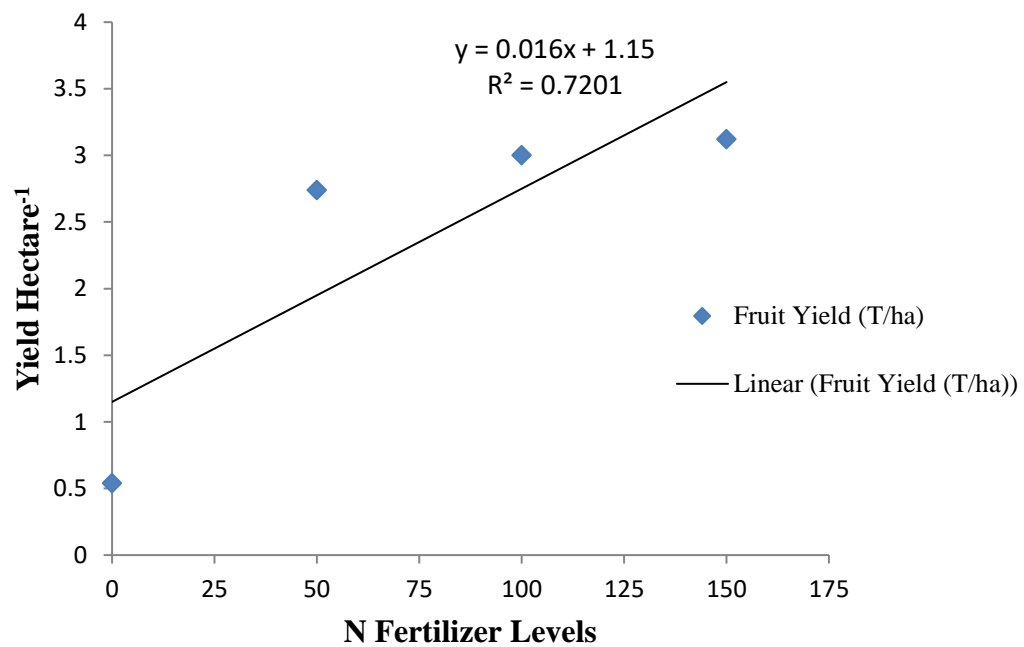


Figure 1: Effect of Nitrogen Fertilizer on Fruit Yield per Hectare at BUK

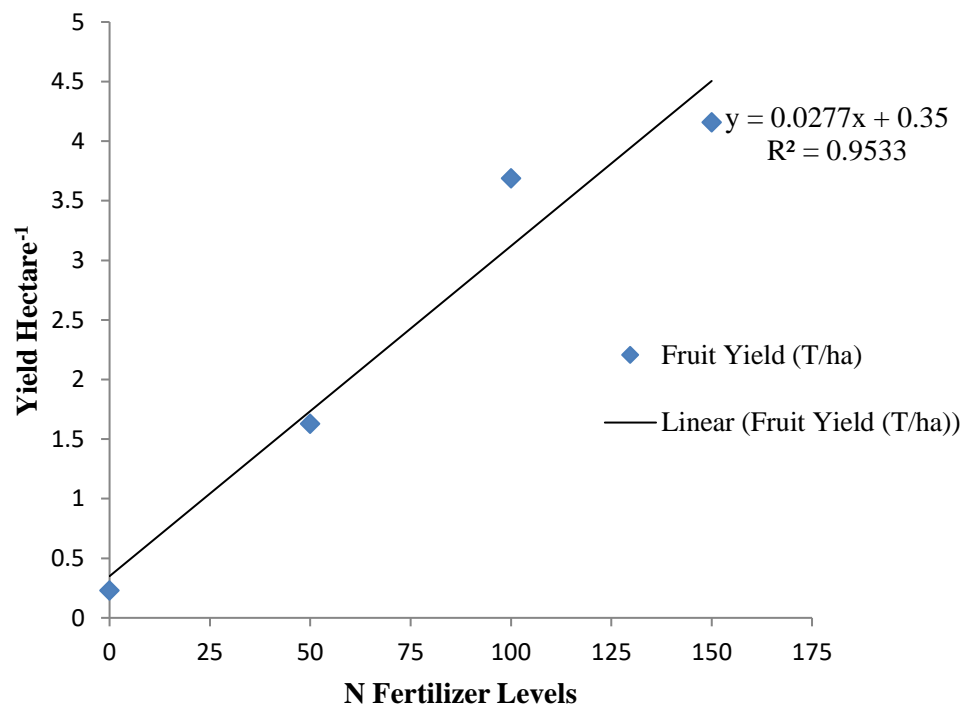


Figure 2: Effect of Nitrogen Fertilizer on Fruit Yield per Hectare at Bagauda

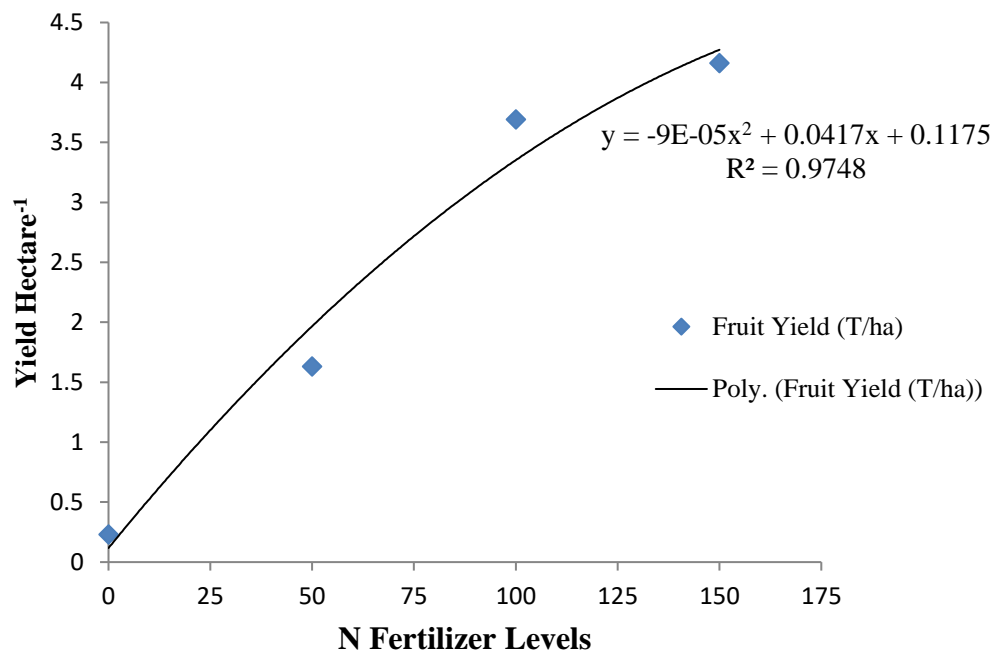


Figure 3: Effect of Nitrogen Fertilizer on Fruit Yield per Hectare at Bagauda

4. Discussion

Total fruit yield per hectare showed positive and highly significant association with total yield plant⁻¹, aborted flower, and blossom end rot, number of fruit plant⁻¹, number of flower cluster⁻¹ and number of fruits per fruit cluster, indicating that early flowering and fruitfulness were the most important yield components for rainy-season tomatoes, therefore, any improvement of these characters would result in a substantial increment on fruit yield. This is in agreement with Ghosh *et al.*, (2010) who reported that number of fruits per cluster, flower per clusters per plant and fruits per plant had positive and highly significant association with fruit yield. Similarly, Hidayatullah *et al.* (2008) reported positive association of fruit yield per plant with number of fruits plant⁻¹ and number of pickings.

Nevertheless, fruit yield showed significantly negative association with number of cracked fruit, days to 50% flowering, fruit length, although fruit length percentage was negligible. This explain that early maturity variety gave higher fruit yield per hectare than the late variety in the environment. As earlier reported that negative correlations prohibit the simultaneous improvement of those traits (Tiwari and Devendra, 2011). Hence, explain that in the specific case of flowering, genetic factors controlling flowering in tomato tell plants when to start making flowers and hence fruits (Krieger *et al.*, 2010), whereas environmental factors such as high temperature, rain splashes, and winds may favor early flowering tomatoes through escape, and hence causing yield to be negatively correlated to flowering time, as in this paper. Similar results were obtained by Singh and Cheema (2005). This clearly explains that number of fruit plant⁻¹, number of flower cluster⁻¹ and number of fruits per fruit cluster found to be important yield components in the tomato varieties studied. Thus, emphasize the need for careful consideration of factors such as flowering time, fruit length, and the occurrence of blossom end rot and fruit cracking in tomato cultivation practices. By understanding these correlations, farmers and researchers can make informed decisions to optimize yield and quality in tomato production.

When fruit yield per hectare was regressed against N fertilizer levels, the study observed a notable variation in the response of the tested tomato varieties to nitrogen (N) fertilization. In the Bagauda region, the relationship between N rates and tomato yield showed both linear and quadratic positive regressions. The linear regression had a coefficient of determination (R²) of 0.95, indicating a strong correlation, while the quadratic regression had an even higher R² value of 0.97, suggesting a more robust relationship. On the other hand, in the BUK region, the relationship

between N rates and tomato yield exhibited a linear positive regression, with an R^2 value of 0.72. Although slightly lower than the values observed in Bagauda, it still indicated a significant correlation between N fertilization and tomato yield. The highest fruit yield of 4.16 t ha^{-1} was obtained with application of fertilizer rates of 150 kg N ha^{-1} , application of N consistently and markedly increased fruit yield. Similarly, tomato fruit yield increased with increasing N concentration, with a quadratic relationship with regard to fruit yield and N applied on tomatoes was reported by Smith (1966). As in this study, the relationship of fruit yield to N concentration fitted a linear model; thus, in line with the study of Tei *et al.* (2002) reported a linear response of yield of tomatoes to N rates up to 400 kg ha^{-1} , whereas Aref *et al.* (2002) found that maximum yields of fresh market tomatoes were achieved at 202 kg N ha^{-1} . Overall, these findings highlight the importance of N fertilization in tomato production and demonstrate the variability in the response of different varieties in different regions, as different areas may exhibit varying trends in the relationship between N rates and tomato yield. The results suggest that careful management of N fertilization can significantly influence tomato yield and guide farmers in optimizing their fertilizer practices for improved crop productivity.

5. Conclusion

The study demonstrated the importance of early flowering and fruit set as key factors influencing fruit yield in rainy-season tomatoes and unveiled a noteworthy association between fruit weight and flower abortion with fruit yield per plant in both study locations. This correlation implies that early flowering and fruitful characteristics play pivotal roles as key components for achieving optimal yield in rainy-season tomatoes. Hence, It emphasized the need to avoid tomato varieties with high rates of flower abortion and to incorporate flower abortion manipulation in the selection criteria for breeding tomato genotypes with improved fruit yield and quality. Furthermore, the study highlighted the impact of nitrogen fertilization on fruit yield, with Bagauda experiencing a linear increase and BUK reaching optimal yield at $150 \text{ kg N per hectare}$. Thus, a recommended N fertilizer level of 150 kg N/ha can be suggested for tomato production during the rainy season. These findings provide valuable insights for enhancing tomato production in different locations during the rainy season.

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Supplementary Materials

Table 2: Physical and Chemical Properties of the Soil at BUK and Bagauda.

Soil properties	BUK	BAGAUDA
Physical (%)		
Sand	65	52
Clay	12	15
Silt	23	33
Textural Class	Sandy-loam	Sandy-loam
Chemical		
pH	7.2	7.34
Organic Carbon (g kg ⁻¹)	0.35	0.42
Total Nitrogen (g kg ⁻¹)	0.02	0.39
Available P (mg kg ⁻¹)	21.26	17.62
Exchangeable base (cmol kg⁻¹)		
Ca	4.25	3.50
Mg	0.81	1.25
K	0.29	0.54
Na	0.48	0.13
CEC	6.05	10.6

Appendix 1: Meteorological Data during 2014 Rainy Season at Bagauda

Months	Rainfall (mm)	Max. Temperature(°C)	Min. Temperature(°C)	Relative Humidity
May	17.00	35.04	27.15	41.06
June	4.79	35.25	24.45	46.56
July	29.33	31.90	22.91	57.61
August	55.07	29.90	23.63	62.54
September	23.81	31.49	23.69	52.43
October	45.20	32.60	22.71	59.87
Mean	29.2	32.69	24.09	53.35

Source: Meteorological Station, National Research Institute for Horticulture, Sub-station Bagauda, Kano

Appendix 2: Meteorological Data during 2014 Rainy Season at BUK

Months	Rainfall (mm)	Max. Temperature(°C)	Min. Temperature(°C)	Relative Humidity
May	2.19	36.75	23.86	29.52
June	1.02	36.09	23.53	37.472
July	5.31	32.42	21.85	51.71
August	10.03	30.29	20.14	61.52
September	4.47	31.49	20.64	90.83
October	0.8	34.33	18.71	45.38
Mean	3.97	33.56	21.46	52.74

Source: Meteorological Station, Soil Science Department, Bayero University, Kano