Comparative Assessment of Adaptability and Agronomic Traits of Seventeen Tomato Varieties on Coarse-Textured Soil in Tropical Dry and Rainy Seasons

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Summary

Though tomato is sensitive to humidity, tomato lines introduced to humid tropical environments are rarely assessed for relative performance in the prevailing seasons. The agronomic traits of 17 tomato varieties grown on a sandy-loam soil in the derived savannah were assessed in successive dry and rainy seasons. The varieties generally performed poorer in the dry than the rainy season, mostly showing incongruent trends in the two seasons. 'Ekwunato' and 'Tomato Mmiri' were the tallest with the most nodes in the dry and rainy seasons, respectively. 'Ekwunato' and 'Yolince' attained 1st flowering earliest, whereas 'Ekwunato' and NACGRAB-5 produced the most flowers and fruits in the dry and rainy seasons, respectively; 'Starke Aryes' had the fewest in both seasons. However, 'Ronata' and NACGRAB-9 gave the highest fruit weight per plant (3892 and 3820 g, respectively) in the dry season, before 'Tropimech' (3245 g). NACGRAB-9 gave the highest (8,475 g) weight in the rainy season, before 'Ekwunato' and 'Ronata' (7632 and 7513 g, respectively). Positive character associations prevailed among numbers of nodes, leaves, trusses, flowers and fruits per plant in both seasons. Numbers of days to 1st and 50% flowering were negatively correlated to the number of fruits per plant. However, fruit weight per plant had no correlations with the other traits. 'Ekwunato' and NACGRAB-5 could serve as gene donors in breeding for enhanced flowering/fruiting in dry and rainy seasons, respectively. To increase tomato fruit yields, NACGRAB-9 or 'Ronata' is recommended, otherwise 'Tropimech' and 'Ekwunato' should be grown specifically in dry and rainy seasons, respectively.

Key words

Solanum lycopersicum, high humidity, tropical seasons, germplasm assessment, fruit yield

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Received: March 28, 2022 | Accepted: February 28, 2023 | Online first version published: July 20, 2023

Introduction

Mere identification of improved vegetable varieties is not enough to achieve all-season production needed to meet the ever-increasing demand. In tomato (*Solanum lycopersicum* L), most traits are of agronomic relevance and cannot be studied using model plant systems. The tomato fruit contains the bioactive substances carotenoids (lycopene, β-carotene and lutein) and phenolics (flavonoids, phenolic acid and some tannins), as well as vitamins C, E and B (Ilahy et al., 2011; Raiola et al., 2014). These organic compounds and vitamins are often reported to have anti-inflammatory and anti-cancer effects in humans for which they help in preventing some chronic diseases (Kris-Etherton et al., 2002; Giovannetti et al., 2012; Zu et al., 2014).

Variability within a species is a valuable tool for screening and genetic improvement. Though this variability is mostly found among wild relatives of field crops, gene introduction is used to increase biodiversity and plant productivity in any agro-environment. In Nigeria, production of tomato is mainly with varieties introduced mostly from temperate countries (Olaoye et al., 2014). Such exotic materials are often treated to reduce the risk of pathogens, but their performance may not be optimal because of differences in climate. The use of exotic materials to enlarge the genetic variability of germplasms in Nigeria may, therefore, not be as viable as collection and assessment of the many local varieties.

However, poor understanding of genetic expression of a variety in a new environment may hinder successful introduction. High yield is a major objective of breeders and growers (Wang and Li 2008; Xing and Zhang 2010). Crop varieties are often assessed in field trials for gene effect. Such assessment makes for enhanced understanding of species diversity and character associations which could guide the search for materials for direct introduction as cultivars or for use in providing genetic variability in breeding for desired traits. It is also used to assess variety adaptability and performance in any agroecological condition. Tomato yield is influenced by genetic variations among cultivars, their growth environment, and cultural practices adopted (Ortiz et al., 2007). Selecting ideal cultivars for a given region and adopting the best management practices could thus help to boost productivity.

When varieties have desirable traits, they are often subjected to multi-location trials to measure the influence of geographic environment on the gene(s) responsible for such traits. In the humid tropics of distinct dry and rainy seasons, location-specific recommendations of varieties are often made regardless of season (Oraegbunam et al., 2016). This is despite the influence of rainfall seasonality on microclimate and soil moisture regime and, hence, the entire biophysical environment. Such changes in biophysical environment could, like differences in geographic environment, influence genetic expression of agronomic traits by varieties. This may be particularly true for tomato on droughty tropical soils, considering the potential role of humidity in its production. To our knowledge, this hypothesis is yet to be tested. Field trials on tomato cultivars in the Nigerian Derived Savannah have been restricted to the rainy season (Uguru and Atugwu 2000; Oko-Ibom and Asiegbu 2006; Onyia et al., 2019), making the testing of the above hypothesis in the zone imperative.

Therefore, this study was carried out in successive dry and rainy seasons at Nsukka in the Derived Savannah zone of Nigeria, using well-drained coarse-textured soil and involving 17 tomato varieties. The objective was to assess these tomato varieties for adaptation and subsequent growth, flowering and fruiting in the dry season relative to the rainy season.

Material and Methods

Study Environment

This study was conducted at the University of Nigeria Teaching and Research Farm at Nsukka (0.6° 52'N, 07° 24'E; 447.26 m asl) in the Derived Savannah zone. The area has a humid tropical climate with two distinct seasons; dry season (Nov. - Mar.) and rainy season (Apr. - Oct.). Rainfall distribution is bimodal, with peaks usually in July and October. Mean annual total rainfall is 1600 mm, and is often less than the mean annual evapotranspiration in recent years. Temperature is evenly high all-year-round, with mean minimum and maximum values of 21 °C and 31 °C, respectively, though the latter can approach 35 °C during the hottest months. Relative humidity rarely falls outside the range 55-80% throughout the year.

The soil at the experimental site, derived from false-bedded sandstones, is deeply weathered, brownish red in colour, coarse-textured, excessively porous and well drained. The soil is classified as Acrisols by the FAO World Reference Base for Soil Resources, and this corresponds to Ultisols by the USDA Soil Taxonomy. In its control section, the soil has an ustic moisture regime and an isohyperthermic thermal regime. Soil moisture storage in the core of the rainy season could range between 180 and 240 mm m^{-1} (Obalum et al., 2012). The prevailing vegetation is grassland interspersed with leguminous species thus typifying the area as derived savannah in southeastern Nigeria.

The field experiments were carried out from Oct. 2015 to Feb. 2016 (dry season trials) and from mid Apr. to Aug. 2016 (rainy season trials). The dry and rainy season trials thrived on irrigation and rainfall, respectively. Key properties of the soil have been shown elsewhere (Obalum et al., 2017; Umezinwa et al., 2020). In brief, the top-(0-20 cm) soil has mean sand, silt and clay contents of 750, 70 and 180 g kg^{-1}, respectively (texture class, sandy loam). The soil is acid (pH, 4.8), with soil organic C, total N, Bray-2 available P and cation exchange capacity (CEC) as 17.88 g kg^{-1}, 0.56 g kg^{-1}, 10.50 mg kg^{-1} and 12.40 cmol kg^{-1}, respectively.

Field Establishment and Management

Seventeen tomato varieties were assessed, including 'NACGRAB-1', 'NACGRAB-3', 'NACGRAB-4', 'NACGRAB-5', 'NACGRAB-6', 'NACGRAB-8' and 'NACGRAB-9', obtained from the National Center for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Nigeria. Others were 'Rio Grande', 'Roma VF', 'Ronata', 'Starke Ayres', 'Tima' and 'Tropimech', procured from the seed sector of a commercial tomato production outfit in Kano State, Nigeria. The remaining four varieties 'Derica', 'Ekwunato', 'Tomato Mmiri' and 'Yolince' were sourced locally from farmers around the Nsukka study area.

To raise seedlings tomato seeds were sown in nursery raffia baskets (60 cm × 20 cm), containing a planting medium of topsoil, poultry droppings and sawdust in a ratio of 3:2:1 (v:v:v). Cultural practices such as providing shade over the nursery and routine watering and weeding were observed (Adubasim et al., 2018). The experiment was arranged in a randomized complete block design with three replications; the field was divided into three blocks each containing 17 plots for the 17 tomato varieties. Plots measured 3 m × 2 m. Distances of 1.0 and 0.5 m were maintained between blocks and plots, respectively.

Land preparation was done manually. As basal soil amendment, poultry-droppings manure was applied at a rate of 8 t ha^{-1} one week prior to transplanting. Raised beds were made for seedlings transplanting at a space of 60 × 45 cm, with 20 seedlings per plot. The seedlings were transplanted four weeks after raising them in the nursery. Because of the agronomic benefits combining manure and compound fertilizer in the study (Nnadi et al., 2019), the basal manure was augmented with NPK 15:15:15 fertilizer applied at 90 kg ha^{-1} three weeks after transplanting (WAT). Transplanting in the dry season planting was done in early Nov. 2015 when the dry season had set in; the corresponding date in the rainy season planting was mid Jun. 2016 when the rains had stabilized.

In the dry season, the plots were manually 'irrigated' using 10-L sprinkler cans, adding ca. 30 L per plot twice (morning and evening) daily. This quantity of water on the 6-m^2 plots of this study translates into irrigation depth of 5 mm at each watering event. In the study area, conservative estimate of field capacity is put at 30% (Obalum et al., 2011a), translating into adding 90 mm of water onto the topsoil (0-30 cm) when dry. From experience, ca. 18 mm restores the topsoil to field capacity every two days. So, the 'split-dose' watering adopted here was not to recharge the soil to field capacity at any time, but to compensate for the high evapotranspiration rate in the study area which in the dry season could exceed 5 mm day^{-1} (Obalum et al., 2011b), and which the addition of 5 mm twice daily was expected to take care of. Also, this watering scheme gave no room for uncontrollable percolation but promoted water retention in the root zone. For these reasons it was deemed a better water management plan in this study than the conventional targeting at field capacity.

Data Collection and Analyses

Data collection utilised the four middle row plants in a plot. Plant height was measured and nodes and leaves counted at 2, 4 and 6 WAT. During the reproductive phase, number of days to 1st and 50% anthesis (flowering) were recorded and the interval was noted. Numbers of flowers per truss, trusses per plant and flowers per plant were counted. Harvest lasted from fruiting till senescence. Number of fruits and fruit weight were recorded at each harvest and, thereafter, the cumulative values averaged for the plants in a plot to get the amount per plant.

The data were analysed as for experiments in randomized complete block design, using the software GenStat Discovery Ed. 4 (VSN Int. Ltd., Hempstead, UK). The F-LSD was used to separate means when the F-test was significant. The two seasons were analysed separately to enable comparative assessment of the varieties in each season. The software SPSS Version 16 was also used (i) for Pearson correlations among the agronomic traits assessed, and (ii) to compare the seasons by independent T-test. In both the correlation analysis and the T-test, mean values of the data for plant height and numbers of nodes and leaves that involved sampling over 2-6 WAT, rather than the values for the individual sampling stage, were used.

Results

Growth Attributes of the Tomato Varieties

Variety influenced all the growth, flowering and fruiting parameters assessed of the tomato varieties in both seasons of the study, with generally poorer performance in the dry season compared to the rainy season (Fig. 1-9). Differences in plant height at 2, 4 and 6 WAT are shown in Fig. 1. In the dry season, 'Ekwunato' was always the tallest, but was similar to few others including NACGRAB-1 at 2 WAT and NACGRAB-1 and 'Tomato Mmiri' at 4 WAT. 'Tima' consistently showed the shortest plants, though it was similar to 'Rio Grande' and 'Tropimech'. In the rainy season, 'Tomato Mmiri' was consistently the tallest and was similar to few others including NACGRAB-4, NACGRAB-8 and NACGRAB-9 at 4 and 6 WAT. 'Yolince' was always the shortest. Notably, NACGRAB-5, 'Roma VF', 'Ronata', 'Starke Aryes' and 'Tima' exhibited congruent growth pattern in both seasons more than the other varieties.

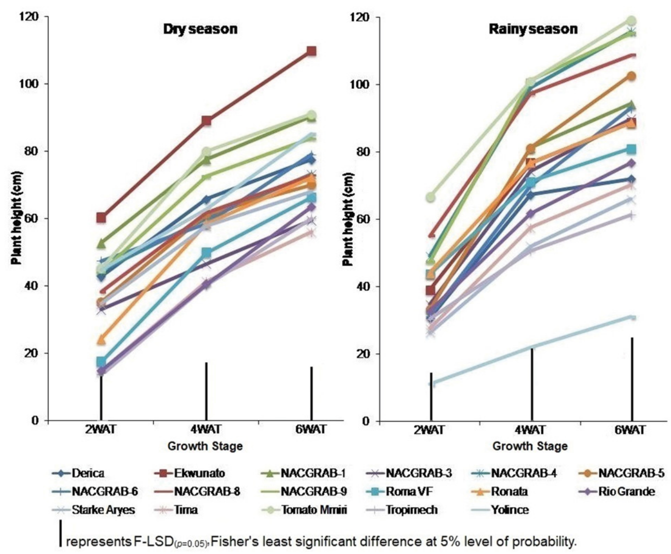

Figure 1. Influence of tomato variety on plant height at 2, 4 and 6 weeks after transplanting (WAT) in the dry and rainy seasons at Nsukka, southeastern Nigeria

Fig. 2 shows the differences in number of nodes per plant among the tomato varieties. In the dry season, 'Ekwunato' and 'Tomato Mmiri' had the most nodes, and were similar to 'Derica', NACGRAB-5, NACGRAB-6, NACGRAB-9 and 'Ronata'. The fewest nodes were counted in 'Tima', 'Tropimech' and 'Rio Grande'. In the rainy season, 'Tomato Mmiri' had the most nodes, followed by NACGRAB-8 at 2 WAT but by NACGRAB-5 at 4 and 6 WAT. 'Starke Aryes' always had the fewest nodes, followed by 'Rio Grande', 'Tima' and 'Tropimech'.

Fig. 3 shows the varieties' number of leaves per plant. In the dry season, 'Ekwunato', NACGRAB-5, NACGRAB-6, NACGRAB-9 and 'Tomato Mmiri' always had the most leaves; 'Rio Grande', 'Tima' and 'Tropimech' always had the fewest. In the rainy season, 'Tomato Mmiri', NACGRAB-4, NACGRAB-5 and NACGRAB-8 had the most leaves, though with more leaves in 'Tomato Mmiri' than the rest at 2 WAT. As observed for number of nodes per plant, 'Starke Aryes' always had the fewest leaves, followed by 'Rio Grande', 'Tima' and 'Tropimech'.

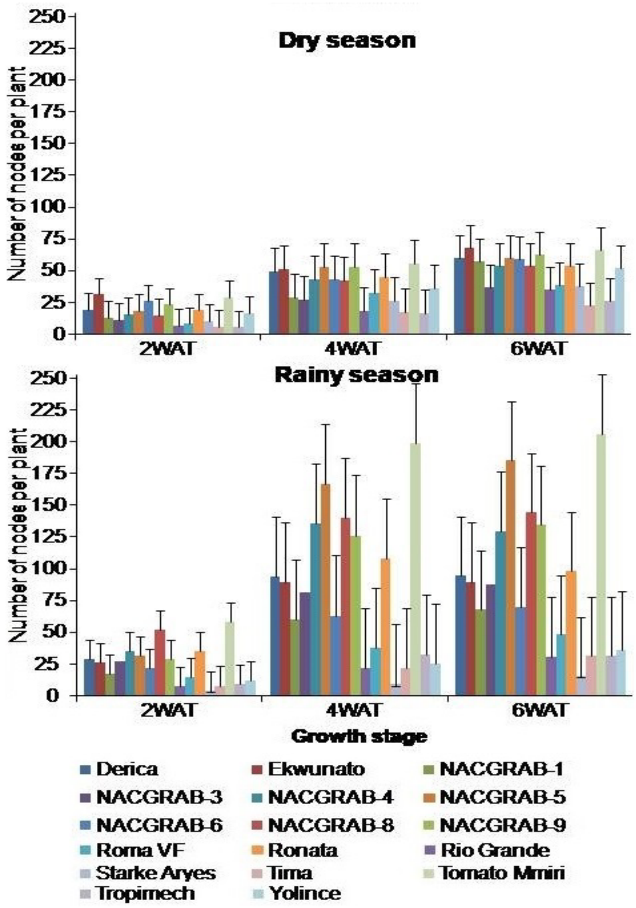

Figure 2. Influence of tomato variety on number of nodes per plant at 2, 4 and 6 weeks after transplanting (WAT) in the dry and rainy seasons at Nsukka, southeastern Nigeria

Note: Error bars represent F-LSD$_{(p=0.05)}$, Fisher's least significant difference at 5% probability level

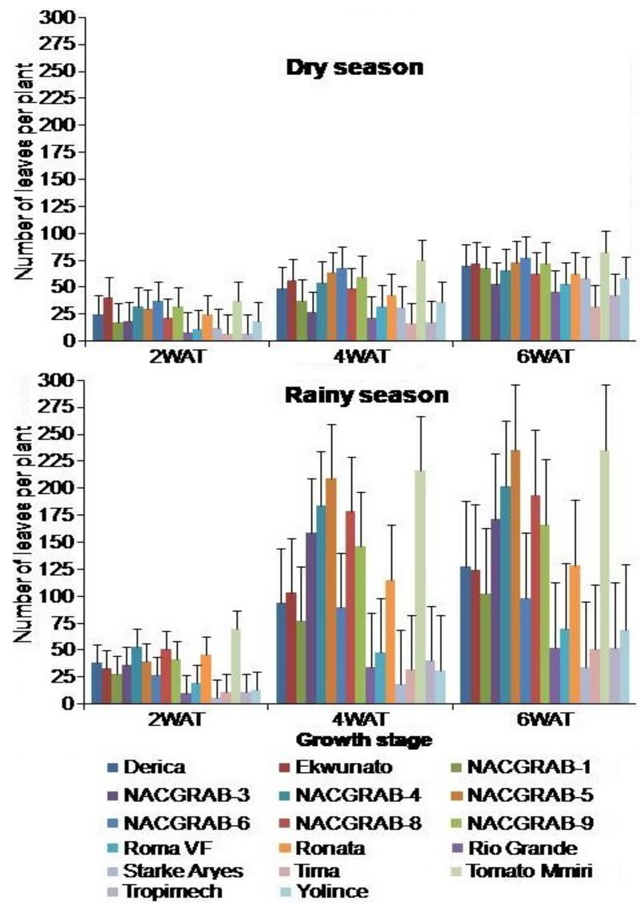

Figure 3. Influence of tomato variety on number of leaves per plant at 2, 4 and 6 weeks after transplanting (WAT) in the dry and rainy seasons at Nsukka, southeastern Nigeria

Note: Error bars represent F-LSD$_{(p=0.05)}$, Fisher's least significant difference at 5% probability level

Flowering of the Tomato Varieties

Time to 1st and 50% flowering of the varieties is shown in Fig. 4. In the dry season, 'Ekwunato' recorded the fewest days to first flowering, and was similar to 'Tomato Mmiri', NACGRAB-4 and NACGRAB-6, among few others. 'Rio Grande' took the longest to flower and was similar to 'Tima', 'Tropimech' and three others. NACGRAB-4 took the fewest days to attain 50% flowering, followed by NACGRAB-1. Again, 'Rio Grande' took the longest, followed by 'Tropimech'. However, the shortest period from 1st to 50% flowering was recorded for 'Rio Grande', followed by 'Tropimech'. The longest period was recorded for NACGRAB-6, followed by 'Ekwunato'. In the rainy season, 'Yolince' recorded the fewest days to flower; 'Starke Aryes' recorded the most, followed by 'Tima'. NACGRAB-8 and 'Starke Aryes' took the shortest and the longest time, respectively to 50% flowering. The shortest period between 1st to 50% flowering was recorded for NACGRAB-6, followed by 'Tima'. The longest period was for 'Ekwunato', followed by NACGRAB-5 and 'Rio Grande'.

Fig. 5 shows the varieties' number of trusses per plant. In the dry season, 'Ekwunato' gave the most trusses, followed by NACGRAB-9, NACGRAB-5 and 'Yolince'. The fewest trusses per plant were counted in 'Roma VF' and 'Starke Aryes'. In the rainy season, NACGRAB-5 and 'Starke Aryes' gave the most and the fewest trusses, respectively. Parallel to its trussing trait, NACGRAB-5 had the most flowers per truss in both seasons, while 'Ekwunato' and NACGRAB-9 showed intermediate values (Fig. 6). Also shown is the varieties' number of flowers per plant (Fig. 7). In the dry season, 'Ekwunato' produced the most flowers, followed by NACGRAB-9. In the rainy season, it was NACGRAB-5, followed by 'Yolince'. 'Starke Aryes' had the fewest flowers in both the dry and the rainy seasons.

Fruiting of the Tomato Varieties

The number of fruits per plant produced by the tomato varieties is presented in Fig. 8. In the dry season, 'Ekwunato' produced the most fruits, more than NACGRAB-4, NACGRAB-5, NACGRAB-6 and NACGRAB-9 with similar values. In the rainy season, NACGRAB-5 produced the most fruits, more than NACGRAB-4, NACGRAB-6, NACGRAB-8 and NACGRAB-9 for which values were similar. Again, 'Starke Aryes' produced the fewest fruits in both seasons of the study.

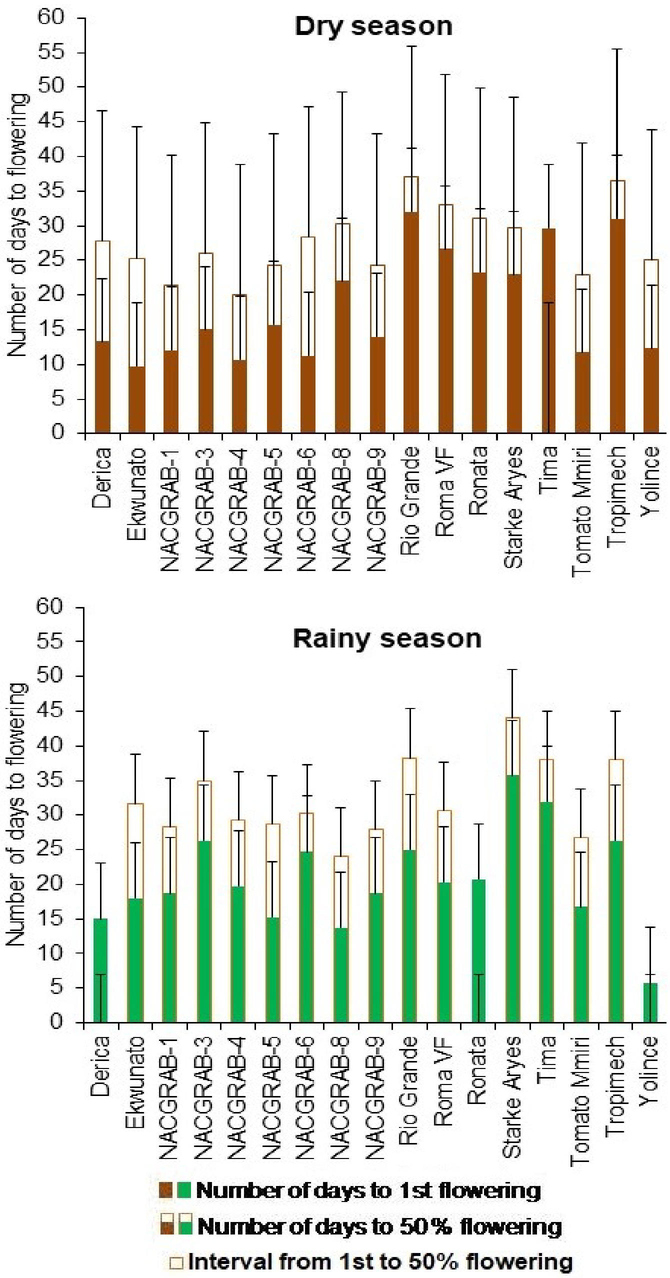

Figure 4. Influence of tomato variety on number of days to 1st flowering and 50% flowering in the dry and rainy seasons at Nsukka, southeastern Nigeria

Note: Error bars represent F-LSD$_{(p=0.05)}$, Fisher's least significant difference at 5% probability level

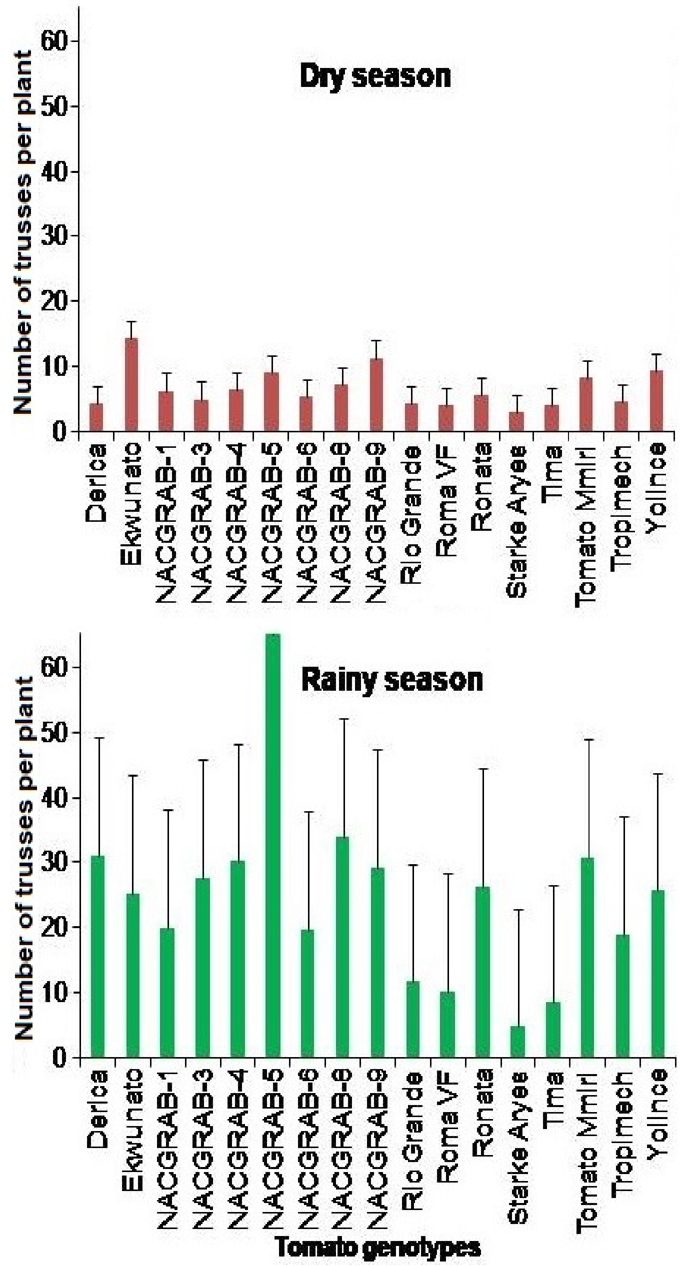

Figure 5. Influence of tomato variety on number of trusses per plant in the dry and rainy seasons at Nsukka, southeastern Nigeria

Note: Error bars represent F-LSD$_{(p=0.05)}$, Fisher's least significant difference at 5% probability level

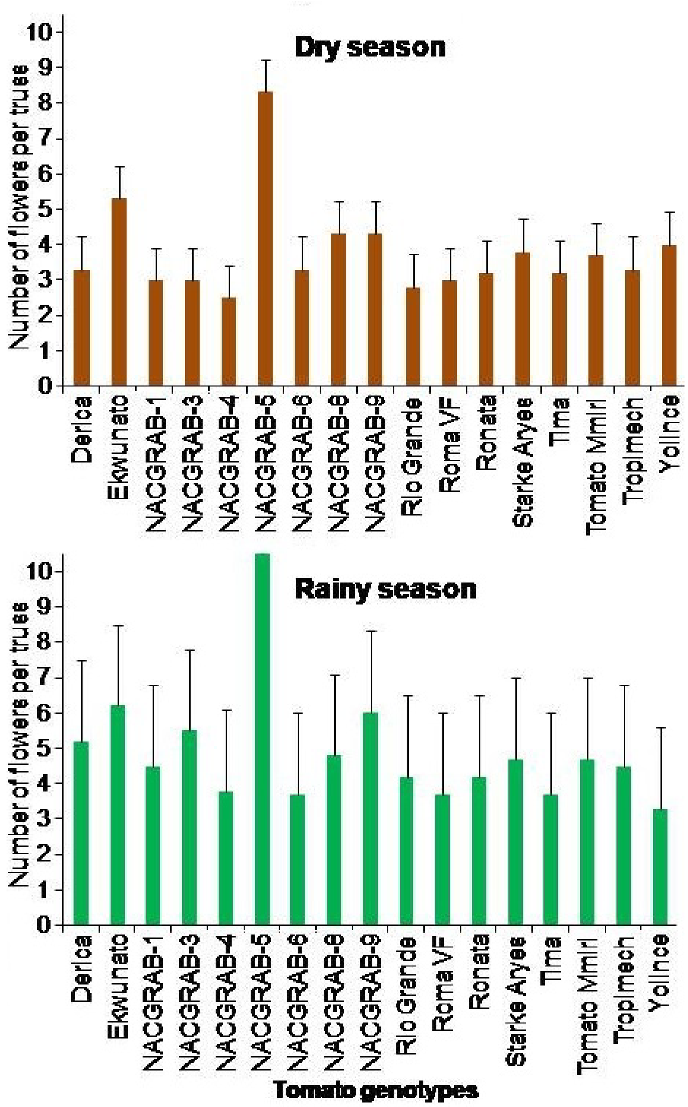

Figure 6. Influence of tomato variety on number of flowers per truss in the dry and rainy seasons at Nsukka, southeastern Nigeria

Note: Error bars represent F-LSD$_{(p=0.05)}$, Fisher's least significant difference at 5% probability level

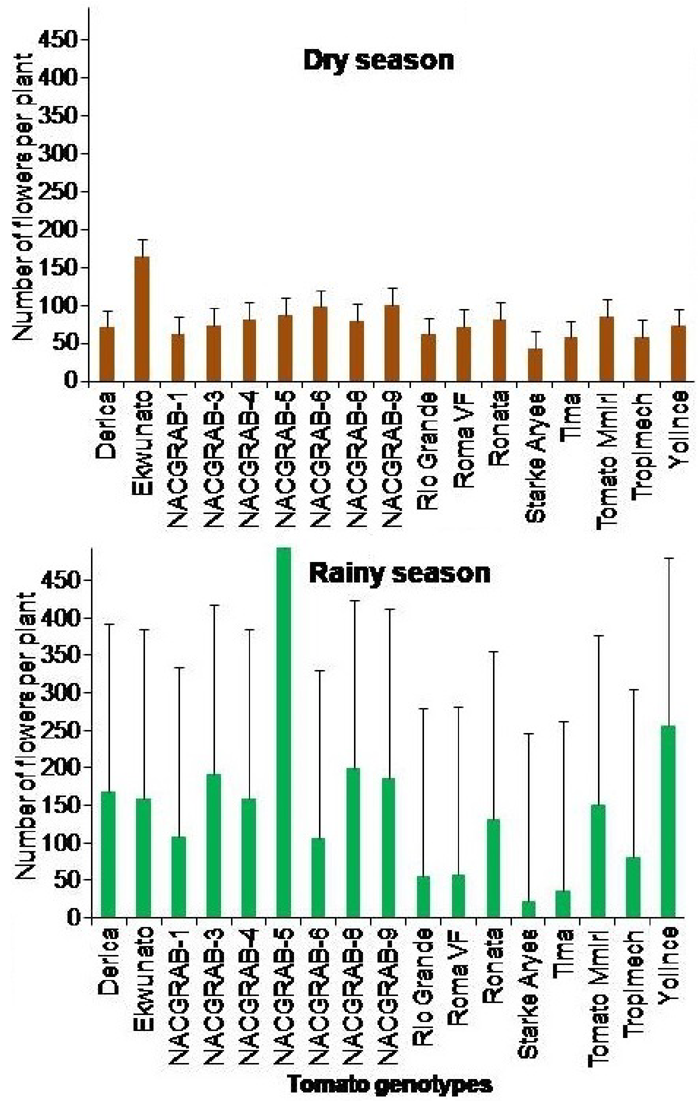

Figure 7. Influence of tomato variety on number of flowers per plant in the dry and rainy seasons at Nsukka, southeastern Nigeria

Note: Error bars represent F-LSD$_{(p=0.05)}$, Fisher's least significant difference at 5% probability level

However, fruit weight per plant followed a different trend (Fig. 9). In the dry season, the weights were highest in 'Ronata' and NACGRAB-9, followed by 'Tropimech', and then NACGRAB-8 and 'Rio Grande'. In the rainy season, it was still NACGRAB-9, followed by 'Ekwunato' and 'Ronata', and then 'Tomato Mmiri'.

Summary of the Influence of Season on Genetic Expression by the Varieties

The influence of season on the agronomic traits of the tomato varieties is summarized in Table 1. Significant correlations existed between dry and rainy seasons except for plant height, number of days to 50% flowering and number of flowers per plant. The T-test validated the overall poorer performance of the varieties in the dry than the rainy season, with nominal differences only for number of days to flowering and number of fruits per plant.

Notably, however, some varieties showed similar values of certain traits in both seasons. For instance, for all the agronomic traits put together, 'Tima' and, to a lesser extent, NACGRAB-6 and 'Tropimech' tended to be insensitive to season (Fig. 1-9). Yet, for a given variety, differences in one trait between seasons did not always cause differences in other supposedly related traits; where they did, the reverse pattern was observed. For instance, 'Ekwunato', which had similar number of flowers per plant, in both seasons produced more fruits per plant but gave lower fruit weight per plant in the dry season when compared to the rainy season (Fig. 7-9). NACGRAB-8 and 'Yolince' had fewer flowers but higher fruit weight per plant in the dry season compared to the rainy season (Fig. 7 and 9).

Table 1. Comparison of the growth, flowering and fruiting traits of the 17 tomato genotypes in the dry and rainy seasons

Agronomic Trait	Dry season	Rainy season	Correlation	t_{cal}
Mean plant height	57.05 (13.55)	65.71 (18.36)	0.33^{ns}	−1.89†
Mean number of nodes per plant	34.24 (11.36)	65.11 (42.25)	0.75***	−3.68**
Mean number of leaves per plant	42.55 (13.76)	86.84 (49.95)	0.71***	−4.42***
Number of days to 1st flowering	18.44 (7.79)	20.74 (7.15)	0.52*	−1.29^{ns}
Number of days to 50% flowering	26.04 (8.28)	26.53 (13.63)	−0.08^{ns}	−0.12^{ns}
Number of trusses per plant	6.66 (3.00)	24.69 (13.68)	0.50*	−5.96***
Number of flowers per truss	3.78 (1.35)	4.89 (1.66)	0.89***	−6.05***
Number of flowers per plant	79.57 (26.53)	151.29 (109.27)	0.30^{ns}	−2.84*
Number of fruits per plant	49.49 (25.98)	59.02 (37.25)	0.42†	−1.11^{ns}
Weight of fruits per plant	1326.18 (1388.59)	2617.94 (3047.82)	0.72***	−2.34*

Note: Values are means (std errors of means); ^{ns} - non-significant, † - marginally significant ($0.05 > P \leq 0.10$);
*, ** and *** - significant at $P \leq 0.05$, 0.01 and 0.001, respectively

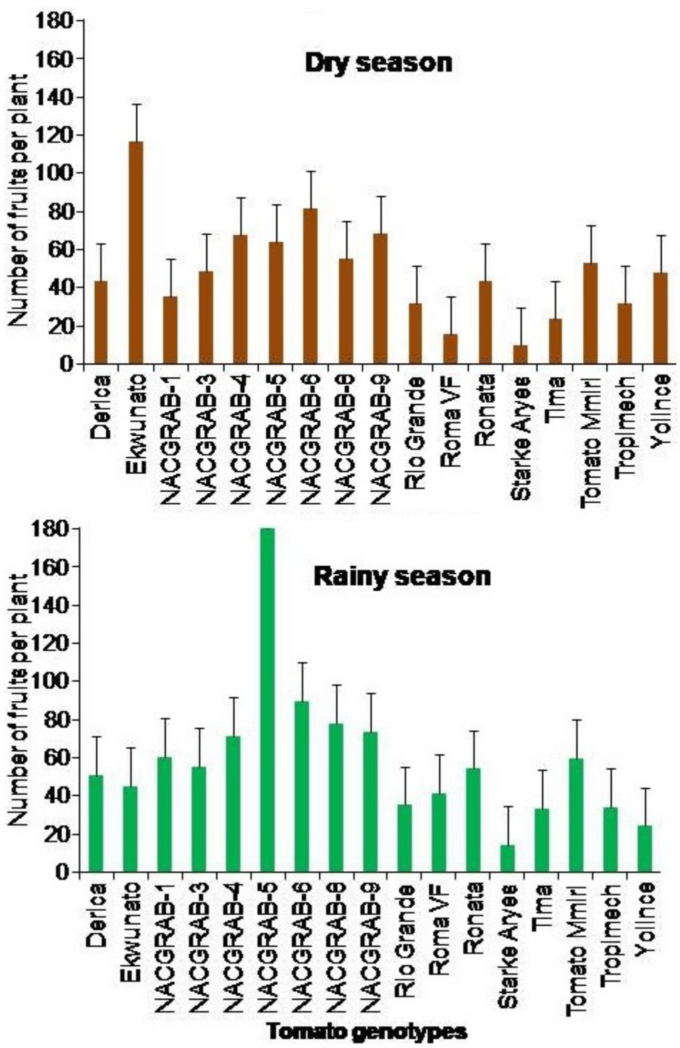

Figure 8. Influence of tomato variety on number of fruits per plant in the dry and rainy seasons at Nsukka, southeastern Nigeria

Note: Error bars represent F-LSD$_{(p=0.05)}$, Fisher's least significant difference at 5% probability level

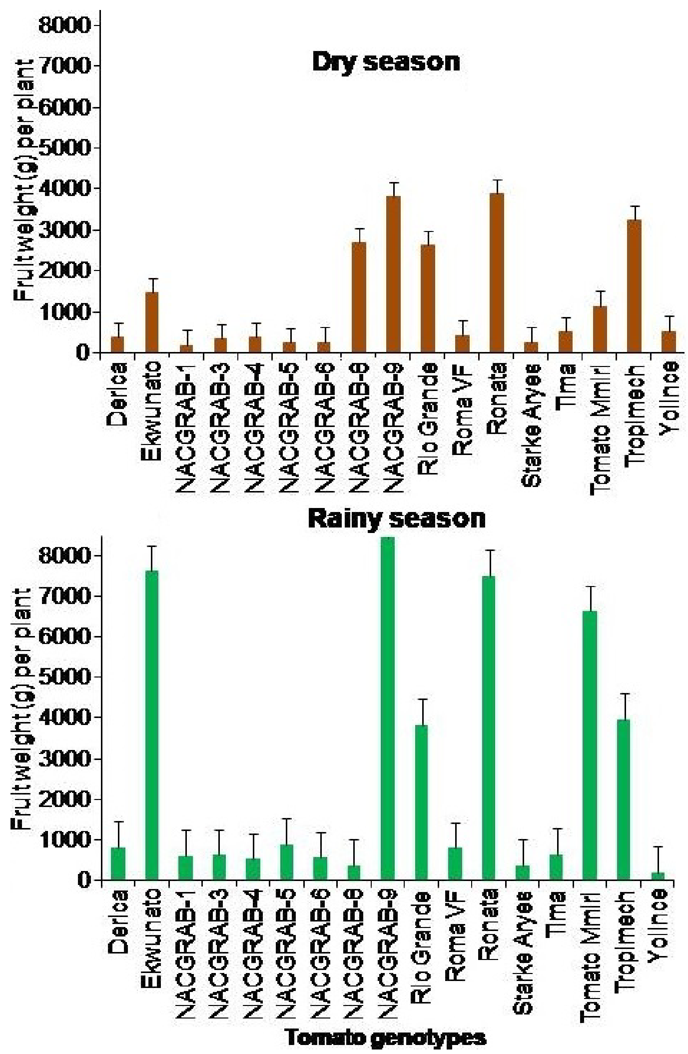

Figure 9. Influence of tomato variety on fruit weight per plant in the dry and rainy seasons at Nsukka, southeastern Nigeria

Note: Error bars represent F-LSD$_{(p=0.05)}$, Fisher's least significant difference at 5% probability level

Agronomic Character Associations among the Tomato Varieties

The coefficients of the correlations between the agronomic traits in the dry and rainy seasons are shown in Table 2. In both seasons, near-perfect positive correlation existed between number of nodes and number of leaves per plant, both traits of which positively correlated with plant height and with each of numbers of trusses per plant, flowers per plant and fruits per plant. In both seasons, negative correlations existed between number of days to 1st and 50% flowering and each of number of nodes and number of trusses per plant, among others.

Table 2 further shows that there were six correlations in the dry season without corresponding correlations in the rainy season, including the negative correlations between number of days to 1st flowering and each of plant height, number of leaves per plant and number of fruits per plant. Others were positive correlations between plant height and each of numbers of trusses, flowers and fruits per plant. Conversely, there were five correlations in the rainy season without corresponding correlations in the dry season, including the positive correlations between both number of nodes and number of leaves with each of numbers of trusses per plant and flowers per truss. Also in this dry season, number of days to 50% flowering correlated negatively with number of fruits per plant. Notably, fruit weight per plant had no correlations with the rest of the agronomic traits in both seasons.

Discussion

In this study, 17 tomato varieties tested in the derived savannah agro-ecology differed in their genetic expression of agronomic traits, similar to reports for some cultivars in Pakistan (Hussain et al., 2001; Ahmad et al., 2007). The tomato varieties thus differ in genetic make-up (Atugwu and Uguru, 2011a). Season also influenced the genetic expression. Tomato yield has been reported to differ in dry and rainy seasons (Agbabiaje and Bodunde 2002). Our study has shown that the nature of such differences depends on variety. The generally lower yields in the dry than the rainy season could be partly due to the adverse effect of high temperatures in the former on plant respiration, assimilate availability and fruit setting (Hussain et al., 2001; Bertin 2005). Also, tomato fruit yield is affected by soil conditions (Ortiz et al., 2007), mainly soil structure and hydraulic properties which can differ between dry and rainy seasons.

Fruit formation, the final outcome of ovary development upon pollination, as well as the accompanying fruit setting directly influences tomato yield which means that fruit set efficiency is a major determinant of fruit yield in tomato (Ariizumi et al., 2013). This is not evident in our study as 'Ekwunato' and NACGRAB-5 that produced the most trusses, flowers and fruits in the dry and rainy seasons, respectively did not give the highest fruit weight per plant. When grown in the rainy season, NACGRAB-5 is of high flowering/fruiting but low yielding ability, not thanks to its small-

Table 2. Matrix of coefficients of the correlations between the agronomic traits of the tomato genotypes in the dry and rainy seasons (n = 17)

		Mean plant height	Mean no. of nodes per plant	Mean no. of leaves per plant	No. of days to 1st flowering	No. of days to 50% flowering	No. of trusses per plant	No. of flowers per truss	No. of flowers per plant	No. of fruits per plant	Weight of fruits per plant
		Rainy season									
Mean plant height			0.813***	0.809***	−0.110^{ns}	−0.865***	0.391^{ns}	0.271^{ns}	0.166^{ns}	0.475^{ns}	0.365^{ns}
Mean no. of nodes per plant		0.837***		0.973***	−0.483*	−0.795***	0.774***	0.498*	0.603**	0.658**	0.319^{ns}
Mean no. of leaves per plant		0.783***	0.964***		−0.436^{ns}	−0.764***	0.788***	0.506*	0.632**	0.678**	0.213^{ns}
No. of days to 1st flowering		−0.846***	−0.799***	−0.805***		0.922***	−0.597*	−0.174^{ns}	−0.626**	−0.313^{ns}	−0.073^{ns}
No. of days to 50% flowering	Dry season	−0.730***	−0.649**	−0.668**	0.911***		−0.611*	−0.220^{ns}	−0.520^{ns}	−0.581*	−0.150^{ns}
No. of trusses per plant		0.746***	0.701**	0.602*	−0.581*	−0.504*		0.786***	0.950***	0.860***	−0.058^{ns}
No. of flowers per truss		0.280^{ns}	0.432^{ns}	0.402^{ns}	−0.229^{ns}	−0.222^{ns}	0.571*		0.782***	0.778***	0.130^{ns}
No. of flowers per plant		0.683**	0.706**	0.644**	−0.545*	−0.325^{ns}	0.838***	0.401^{ns}		0.803***	−0.053^{ns}
No. of fruits per plant		0.688**	0.737***	0.726***	−0.677**	−0.462^{ns}	0.801***	0.401^{ns}	0.923***		−0.068^{ns}
Weight of fruits per plant		−0.134^{ns}	0.014^{ns}	−0.070^{ns}	0.383^{ns}	0.456^{ns}	0.202^{ns}	−0.052^{ns}	0.139^{ns}	0.070^{ns}	

Note: ^{ns} - non-significant; *, ** and *** - significant at $P \leq 0.05$, 0.01 and 0.001, respectively sized fruits (Onyia et al., 2019). Tomato varieties with such traits present ready gene donors in breeding for improvement (Atugwu and Uguru 2011b); so, both 'Ekwunato' and NACGRAB-5 can be used in breeding programmes to enhance flowering cum fruiting in tomato varieties meant for production in dry and rainy seasons, respectively.

'Ekwunato' is a landrace variety adapted and commonly grown in the study area. It was the tallest variety in the dry season, a trait that must be linked to its being the second most yielding in the rainy season, as plant architecture could influence crop adaptation and yield potential (Cai et al., 2016). Also, 'Ekwunato's' ability to relatively flower early and harbour the flowers for a long period would explain its enhanced flowering and fruit setting in the dry season. Variation in timing of flowering can influence inflorescence architecture, flower production and yield (MacAlister et al., 2012). The task of providing assimilates for a dense colony of flowers over a relatively short period may stress the plant.

The correlations between the dry and the rain seasons for the majority of the agronomic traits imply that these traits exhibited similar trends among the varieties in both seasons. These results confer an attribute of consistency in performance pattern to the tomato varieties in the geographic environment of this study, while suggesting that the differences between the two seasons were largely due to biophysical differences between them.

Varieties like 'Tima' which tended to be insensitive to season probably have genes for performance stability and so could be good candidates for breeding against variations due to environmental stress. The inconsistent differences in certain traits between seasons point to the underlying influence of variety and season on genetic expression of traits, specifically on how flowering intensity relates to fruit setting, on one hand and fruit setting to fruit yield, on the other. The results for 'Ekwunato' portray the influence of variety on size and juiciness of tomato fruits (Hussain et al., 2001; Debela et al., 2016), while suggesting that season could also influence these parameters. Also, fewer fruits but higher fruit weight per plant of NACGRAB-8 and 'Yolince' in the dry than the rainy season show the underlying influence of season and variety on how flowering intensity and fruit setting relate to fruit yield. The observation points to the preference of these varieties for less humid growth environments; hence they could be used in breeding for drought tolerance.

The near-perfect positive correlations between number of nodes and number of leaves per plant were expected. The positive correlations between each of numbers of trusses and flowers per plant and number of fruits per plant imply that there was little or no flower drop. Since this observation was consistent in both seasons, flower drop and reduced fruit setting of tomato varieties often reported in the study area in the rainy season would remain attributable to disease complex (Uguru and Atugwu 2000), rather than to the underlying humidity. Increases in numbers of nodes and leaves did not result in corresponding increases in number of flowers per truss in the dry season but in the rainy season, an observation attributed to the higher temperatures in the former which might have aided flower drop (Hussain et al., 2001). Loss of pollens usually experienced with excessive humidity in the rainy season cannot be expected to result in reduced fruit setting in tomato that is a self-pollinating plant.

None of the other traits explained fruit weight per plant. This observation is remarkable but not surprising, since the 17 varieties of this study were involved in the correlations. It seems easier to establish correlations between flowering cum growth traits and fruiting in tomato when rather homogenous units of varieties are involved (Atugwu and Uguru 2011b). For numbers of flowers and fruits per plant, the observation shows that more flowers and fruits may not translate into higher fruit weight, due to the phenomenon of high-fruiting varieties producing small-sized fruits and vice versa (Uguru and Atugwu 2000).

Furthermore, the correlations reveal that tomato varieties which took fewer days to flower generally produced more fruits per plant, as typified by 'Ekwunato'. This is logical, considering that such varieties had longer interval between fruit setting and senescence. Atugwu and Uguru (2011b) note that earliness in flowering favours fruiting in tomato.

Assessing the adaptability and performance of tomato varieties developed or grown elsewhere in agroecosystems where they are newly introduced is vital in identifying those for commercial cultivation or genetic improvement in such new environments. For the derived savannah agro-ecology, whether the tomato grower is interested in dry season or rainy season production is a key determinant in the variety to choose. To increase tomato production on the dominant coarse-textured soils in this agroecosystem, however, growers should cultivate NACGRAB-9 or 'Ronata' regardless of season of the year. Their close substitutes are 'Tropimech' and 'Ekwunato' in the dry and rainy seasons, respectively. The genetic variations among the varieties as expressed in their agronomic traits in the two contrasting seasons of this study could be harnessed in breeding. 'Ekwunato' and NACGRAB-5 could be potential gene donors for increasing fruiting in tomato; 'Tima', NACGRAB-6 and 'Tropimech' for minimizing variations due to environmental stress; and NACGRAB-8 and 'Yolince' for increasing drought tolerance. Consumer preference assessment needs to be carried out on these promising varieties to satisfy market need in the improvement programme.

Acknowledgements

The authors wish to thank the National Center for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Nigeria and Value Seed Limited, Kano, Nigeria, as well as some local tomato farmers in the Nsukka study area of Eastern Nigeria for supporting the study with seeds of the tomato varieties.

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aCS88_21