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EVALUATION OF GENETIC VARIABILITY, HERITABILITY, GENETIC ADVANCE ON GROWTH TRAITS OF TEN TOMATO (*Solanum Lycopersicon* Mill.) GENOTYPES IN NIGERIA

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Abstract

Tomato **(***Lycopersicon esculentum Mill.***)** *is a favorite vegetable crop in Nigeria and around the world. The crop, is plagued with pests, diseases, lack of high-yielding varieties and post-harvest losses. Hence the need of this study to evaluate the genetic diversity, genetic variability, heritability, genetic advance on growth traits of ten varieties of tomato. The study was conducted at Babcock University, Ilishan-Remo and Institute of Agricultural Research and Training (IAR & T), Ibadan. Ten varieties of tomato were selected and planted in nursery for four weeks before transplanting to the field at a spacing of 50 cm x 50 cm (40,000 plants/ha). The experiment was laid out in a randomized complete block design (RCBD) with four replicates. At maturity, data were collected on agronomic and yield traits. Genetic diversity, Genetic variability, Heritability, Genetic advance were estimated on growth traits. Data obtained were subjected to analysis of variance using SAS 9.4, 2013 at P≤0.05, and the means were separated using Duncan's Multiple Range Test. There were significant differences among the genotypes of tomatoes planted in all the characters studied at 1% level of probability in both locations. Roma Savannah produced significantly higher fruit diameter (36.31mm), length (47.97 mm) and weight (38.05 g). TROPIMECH had the highest plant height (0.84 m), number of leaves (38.67) and number of branches (11.83). Plant height and number of fruits were significantly negatively correlated*

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both at phenotypic and genotypic levels (-0.47, -0.59). Plant height and fruit length were negatively correlated at genotypic level (-0.39) while plant height and fruit weight were negatively correlated at genotypic level (-0.60), suggesting that selection directed at plant height will not favour tomato fruit yield. Generally, broad sense heritability ranged from 63.58 to 97.45, suggesting that characters evaluated were also under additive gene control. Characters such as fruit length and number of leaves had high genotypic coefficient of variability, heritability and genetic advance which were reliable predictors of yield. It is therefore recommended that TROPIMECH and UC 82 B varieties be used as putative varieties to improve genetic diversity.

Keywords: *Genetic Variability, Heritability, Genetic Advance, Nutrient content, Tomato.*

INTRODUCTION

Tomato (*Lycopersicum esculentum* Mill) is a major vegetable crop that has achieved tremendous popularity over the last century. It is grown in practically every country of the world with global production of about 89.8 million metric tonnes from an area of about 3,170.000 ha (Osemwegie, *et al*., 2010; Samuel, *et al*., 2011). Tomato is a very popular crop which over time has been a major ingredient in human food all over the world, in Africa and especially in Nigerian dishes (Showemimo, *et al*., 2006). In Nigeria, almost every soup from all the numerous tribes has tomato or tomato products in it. Tomato is not only used as cooking recipe ingredients, tomato fruits are consumed fresh in salads or cooked in sauces, soup and meat or fish dishes. Tomatoes can be processed into purees, juice and ketchup, canned and dried. Tomatoes are the second most-produced vegetable around the world, behind the potato crop (FAO STAT, 2012) and one of the most important crops in West Africa (Showemimo *et al.*, 2006). Tomato is a crop with high nutritional requirements and its production is influenced by the availability of nutrients with greater uptake of macronutrients like Nitrogen, Phosphorus and Potassium (Ferreira *et al*., 2003; Toor *et al*, 2006; Zuba *et al*, 2011). Tomato originated in the Peruvian and Mexican regions and was introduced into Europe by Spanish explorers, later into USA and Canada by European migrants and later introduced from Europe to southern and eastern Asia, Africa and the Middle East (Naika *et al*, 2005). Its origin can as well be traced back to the South American Andes (Bergougnoux, 2014). Tomatoes are also economically important as processed products. Tomato has become an important cash and industrial crop in various parts of the world (Ayandiji and Omidiji, 2011). In developed, developing and even under-developed countries, tomato and tomato paste product are one of the most common products in which the residual by-product is about 3 to 4.8% (Asadollahi, Karimi & Mansuri, 2014).

Diversity can be defined as the variance in genetic and phenotypic characteristics of plants used in agriculture. (Sinha, 2001). Genetic diversity strengthens a population by increasing the likelihood that at least some individuals will be able to survive major disturbances by making the group less susceptible to inherited disorders (McGrath & Kimberley, 1999). This is possible because when an organism contains a large gene pool, the group has a greater chance of flourishing than a population with limited genetic variability. Occurrence of this is as a result of individuals that might have inherited favourable traits such as drought tolerance. Plant breeders take advantage of genetic variants to improve existing plants and create new varieties. Genetic diversity in tomato is also important because it could be used by plant breeders to introduce agronomically favourable traits, increase in nutritional value and also to breed for a higher harvest index (Richard, 2000). Due to the dependency on the relatively small number of crops for global food security, it will be crucial to maintain a high genetic diversity within these crops to deal with increasing environmental stress and to provide farmers and researchers with opportunities to breed for crops that can be cultivated under unfavorable conditions, such as drought, salinity, flooding, poor soils and extreme temperatures (Kirtikar and Basu, 1975). Plant genetic resources are the basis of food security and consist of diversity of seeds and planting

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material of traditional varieties and modern cultivars, crop wild relatives and other wild plant species (Franck, 2005). In Nigeria, few molecular studies have been done on the diversity of tomato (Ezekiel et al., 2011). Most researches are centered on morphological and physiological characteristics.

Morphological characterization of plant species are useful in making thorough investigation of genetic diversity in germplasm collections and this contributes valuable information for breeding programs and conservation strategies for the taxa concerned (Benor *et al.,* 2010). However, such traits are limited in number and are often influenced by the environment, thus making them unsuitable for correct assessment of the genetic diversity (Qi *et al.,* 2003). Irrespective of the limitations of morphological tools in establishing genetic diversity in species, it is readily available especially in the developing countries where the molecular technologies are scarce and expensive to adopt. Morphological techniques, when carefully conducted at several environmental conditions can be used to verify the stability of a genotype and thus become a reliable tool in estimating genetic variability in plant species. Hence my interest in carrying out an assessment of 10 tomato varieties (indigenous and exotic varieties) available to farmers in Nigeria using morphological markers.

Tomato is currently a popular fruit vegetable in Nigeria, however, its production in Nigeria was found to be low, as compared to those of countries in the temperate zones; for example, Nigeria's production was estimated at 1,860,600 tonnes in 2010, while that of the United States of America (USA) was estimated for the same year to be 12,858,700 tonnes, putting yield per hectare in Nigeria at 1/7th of that of the U.S.A (FAO, 2010). 45% (750,000 metric tonnes) of tomatoes produced in Nigeria is estimated as annual loss due to the poor food supply chain (Ugonna *et al*, 2015). Fresh tomato by-products have been considered to be an environmental nuisance for a long time (Rabak, 1917). In some countries, the waste was reported to be dumped in waterbodies near the factory or left to accumulate on the site of production. The material degenerates/rots quickly, emits a very foul odour and provides a breeding place for a variety of pests such as flies and mosquitoes, which are hosts of disease-causing organisms (Caluya *et al*., 2003). These are materials that could have been put to better use in feeding livestock and it may eventually prevent environmental contamination (Del Valle *et al*., 2006; Caluya *et al*., 2003). This study aims to tackle the problem before planting by recommending varieties with desirable traits that are repeatable and that could be used to breed new varieties that will be more productive and resistant to pests and undesirable weather elements. The objective of this study was to determine the genetic diversity among ten varieties of tomato estimate the broadsense heritability and genetic advance of the yield and related characters in tomato;

METHODOLOGY

The study was carried out in two locations, which were Babcock University, Ilishan-Remo, Ikenne Local Government Area, Ogun state, and Institute of Agricultural Research and Training (IAR&T), Apata, Ibadan, Nigeria. The project was hosted in Babcock University, located in Ogun state, in Ikenne Local Government, within latitude 6^{o} 54 N and 7^{o} 28 N of the equator and longitude 3^{o} 42 E and 4^{o} 15 E of the Greenwich Meridian. The average annual rainfall is 1500 mm, with altitude of about 300 above sea level, while the mean annual temperature is about 27 ^{o}C. Ikenne Local Government area, Ogun State is located in the South-Western part of Nigeria. It is bound in the west by the Republic of Benin, in the east by Ondo State, in the south by Lagos State and in the north by Osun and Oyo States. It lies within latitude 6^{o} N and 8^{o} N and longitude 2^{o}E and 5^{o} E. It has a land area of about 16,762 square kilometres and a population of about 3,728,098. Farming is the major occupation of the people, particularly those living in the rural areas. Administratively, Ogun state is divided into four divisions which include, Egba, Ijebu, Yewa and Remo. In all, there are 20 local government areas in the state. The second location was at the Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Oyo State Nigeria. The research station is in the Forest-Savannah mosaic. Ibadan is located in

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south-western Nigeria in the southeastern part of Oyo State at about 119 km (74 miles) northeast of Lagos and 120 km (75 miles) east of the Nigerian international border with the Republic of Benin. It lies within the Forest-savanna mosaic zone but recent logging and other human activities have brought the derived savannah into Ibadan. The city covers a total area of 3,080 km^2 (1,190 sq mi), the largest in Nigeria and West Africa.

The Nursery

Tomato seeds obtained from a reputable seed company (TECHNISEM©) were sown and maintained on a ground nursery for 4 weeks, this was to allow the plants to be well established and have proper vigour before transplanting to the field.

The Field Experiment

The Field experiment was carried out at the Teaching and Research Farm, Department of Agriculture, Babcock University, Ilishan-Remo, Ogun State. This location is in the South Western part of Nigeria with an annual rainfall of 1,500mm, a mean annual sunshine of about 2,100-2,300h and a mean annual temperature of about 27 °C.

Soil Sampling

Initial core soil samples (at 15 cm deep) were collected from the field. The soil samples were bulked, thoroughly mixed, shade-dried and sieved through a 2 mm screen after which a composite sample was taken from the bulk soil for determination of some physico-chemical characteristics of the soil on the field. Total N was determined by the Kjeldahl method described by Bremmer and Malvancy (1982); Available phosphorus was determined according to the method of Bray and Kurtz (1945); soil pH (1:1 soil: water) as determined by the pH meter, the %C was determined by the Walkely and Black method (1934) and the mechanical analysis was done by the hydrometer method of Bouyocous (1962).

Preparation of the Field for Planting

The land was cleared, ploughed and harrowed and beds for planting were prepared using hoes. Tomato transplanting was done to the field when seedlings were 4 weeks old, the seedlings were transplanted at the spacing of 50 cm x 50 cm (40, 000 plants/ha). Two seedlings were transplanted per stand and later thinned to one after establishment at two weeks after transplanting (WAT). NPK 15:15:15 was applied to the allotted plots following Bodunde and Adeniji (2007) method. Weeding was done manually as the need arises.

Layout of the Field Experiment

Letter Notations		Variety of Tomato
V1	=	Roma VF
V2	=	U C 82-B
V3	=	Rio Grande
V4	=	TROPIMECH
V5	=	Roma Savanah
V6	=	Rio Fuego
V7	=	BEEFSTEAK
V8	=	Red Cherry Tomato
V9	=	Hausa Local
V10	=	Yellow Pear

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The experiment was laid out in Randomized Complete Block Design (RCBD) shown in Table 1.

Table 1: Field Experimental Layout for 10 Varieties of Tomato

Block I	Block II	Block III
V10	V3	V2
V4	V9	V5
V7	V4	V6
V8	V7	V8
V1	V2	V3
V3	V6	V9
V9	V8	V7
V2	V1	V10
V6	V5	V4
V5	V10	V1

The data on quantitative and quality characters were recorded on four centrally located, competitive and randomly selected plants in each replication for all the characters under study. The data were analyzed by the methods of Cochran and Cox (1957) using mean values of random plants in each replication from all genotypes to determine significance of genotypic effects. Genotypic and phenotypic coefficients of variation were calculated using the formulae of Burton (1952). Broad sense heritability was calculated as per Lush (1940) and genetic advance estimated by the method of Johnson *et al.* (1955). Categorization of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and genetic advance (GA) were done according to Sivasubramanian and Menon (1973) and heritability categorized following Johnson *et al.* (1955). Broad-sense heritability, assuming a selection intensity of 5% was estimated according to the formula of Allard (1960) and Miller *et al*. (1958) as follows:

$$\text{Heritability (Broad-sense)} = (\sigma^2 g)/ [\sigma^2 g + \sigma^2 e]$$

Where

$\sigma^2 g$ is the estimate of genotypic variance and

$\sigma^2 e$ is the estimate of environmental variance.

Data Analysis

The data obtained were subjected to analysis of variance (ANOVA) using PROC GLM of SAS ver. 9.4 (SAS Institute, Cary, NC, USA; Statistical Analysis System 2013). Mean effects that showed significant F-tests were separated with Duncan Multiple Range Test. Estimates of phenotypic and genotypic variances were calculated from the ANOVA. Broad sense heritability estimates were computed for each environment as the proportion of phenotypic variances that is due to genetic differences among genotypes; the broad sense heritability for the combined locations was estimated according to Tenkouano *et al*. (2002) as:

$$HB=\sigma^2 g/(\sigma^2 g+\sigma^2 ge/l+\sigma^2 e/rl)$$

Where:

HB=the broad sense heritability,

$\sigma^2 g$=the genetic variance,

$\sigma^2 gl$=the variance associated with genotype x location interaction,

$\sigma^2 e$=the experimental error.

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RESULTS AND DISCUSSION

The chemical and physical analysis results of the soil before transplanting at the experimental sites are shown in Table 1. The soils exhibited similarities in the physical and chemical conditions in both locations. This may suggest that variations in crop performance may not strictly be due to soil condition but due to other factors such as climate, soil abiotic and biotic factors as well as genotypic differences (Orcutt and Nilsen, 2000). Other differences in soil nutrient contents can be explained based on the fact that Soil organic matter and clay particles hold large stores of plant nutrients. These reservoirs, however, are not always all available to the crop (Spain *et al* 1983). Understanding the basics of how nutrients are added to and released from soil organic matter holds the key to the variation in other nutrient variations. Also soil type is one of the essential abiotic factors which might affect plant's growth and available nutrients in the soil. Biological factors, soil borne microbes (e.g. root endophytic fungi, mycorrhizal fungi, rhizobia, and plant growth-promoting microorganisms) can also alter the function of plant roots and available nutrients (Chanani *et al* 1998).Result shows that soil from both locations (IAR&T and BU) were sandy-loam and slightly acidic (5.82 and 5.25) respectively. The rest of the available nutrients in the soils from both locations were low except for available phosphorus which was slightly high (22.41 mg kg^{-1} and 24.87 mg kg^{-1}) in IAR&T and BU respectively.

The amount of nutrients taken up by these crops depends on the number of fruit and the amount of dry matter produced. This in turn is influenced by a number of genetic and environmental variables (Shukla and Naik 1993).

Table 1: Result of Soil Analysis at IAR&T and Babcock University (locations)

Parameters	Values for Babcock University	Values for IAR & T
pH (H_2O. 1:1)	5.25	5.82
Sand (gKg^{-1})	860	872
Silt (gKg^{-1})	68	72
Clay (gKg^{-1})	72	56
Exchangeable bases		
Na (c mol kg^{-1})	0.32	0.38
K (c mol kg^{-1})	0.17	0.33
Ca (c mol kg^{-1})	1.00	1.40
Mg (c mol kg^{-1})	4.74	2.67
Ex. Acidity H^+ (c mol kg^{-1})	0.15	0.11
C.E.C (c mol kg^{-1})	6.38	4.89
Av. Phosphorus (mg kg^{-1})	24.87	22.41
Org. Carbon (%)	1.47	0.47
Org. Matter (%)	2.53	1.28
N (%)	0.15	0.07

The results of Analysis of Variance of 9 vegetative and reproductive yield characteristics in 10 varieties of tomato in Babcock University and IAR&T are presented in Tables 2 and 3.

There were significant differences among the ten varieties planted in all the characters studied at 1% ($p \leq 0.01$) probability in Babcock University (Table 2). The result obtained from IAR & T was however different because significant variety effect was observed at 1% ($p \leq 0.01$) level of probability in only seven characters, namely; Plant height, Number of leaves, number of branches, number of fruits, fruit diameter, fruit length and fruit weight. Number of flowers showed significant difference at 5% ($P \leq 0.05$) probability while stem girth, did not show any significant difference among the varieties planted (Table 3). Similarly, there was no replication effect on the characters among the varieties of tomato studied. These observations suggest a wide degree of genetic variability within the 10 varieties studied

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large enough to effectively achieve selection for improvement of the tomato varieties studied. Genetic variability describes the tendency of genetic traits found within populations to vary. This variability provides a genomic flexibility that can be used as a raw material for adaptation by plants or by breeders. On the other hand, one of the consequences of low genetic variability could be the inability to cope with abiotic and biotic stresses. The success of any crop improvement programme depends upon the nature and magnitude of genetic variability existing in breeding material with which plant breeder is working, choice of parents for hybridization and selection procedure. Genetic variability is essentially the first step of plant breeding for crop improvement which is immediately available for germplasm and is considered as the reservoir of variability for different characters.

This study agrees with a study done by Ezekiel, Nwangburuka, Ajibade, and Odebode, (2011) where they concluded that, there was sufficient diversity in tomato crop in Nigeria. This study also is in line with another study that states that exploiting genetically desirable traits is important in order to achieve the rapid genetic improvement of a crop (Denton and Nwangburuka, 2011). Similarly, Singh (1993), asserted that understanding the relative contribution of the various component traits to yield could play significant role in identifying high yielding genotypes. This study further discounts the erroneous practice of grouping tomato varieties generally grown by farmers in Nigeria based on plant and fruit morphology. The study clearly shows that the 10 varieties were totally different when considering many more characters apart from plant and fruit morphology as commonly used by farmers and local consumers.

Table 2: Mean squares of ANOVA of nine vegetative and reproductive yield characteristics of ten varieties of Tomato evaluated at Babcock University Ilishan Remo

Source of variation	df	Plant Height	No leaves	No_branches	Stem Girth	No flower	No fruits	Fruit Diameter	Fruit length	Fruit weight
Block	2	0.03*	9.66	0.32	1.90	5.89	1.15	13.55	85.25	53.24
Genotype	9	0.03**	101.25**	9.04**	10.95**	62.67**	9.01**	294.90**	503.88**	369.25**
Error	18	0.01	4.60	1.83	0.66	5.50	1.29	21.91	60.47	87.95

***Significant at 5% (p≤0.05) level of probability; ** Significant at 1% (p≤0.01) level of probability**

Table 3: Mean squares of ANOVA of nine vegetative and reproductive yield characteristics of ten varieties of Tomato evaluated at IAR & T

Source of variation	df	Plant_height	No_leaves	No_branches	Stem_girth	No_flower	No_fruits	Fruit_diameter	Fruit_length	Fruit_weight
Block	2	0.01	2.13	0.70	0.77	4.90	1.30	78.02**	60.50	40.55
Genotype	9	0.14**	326.28**	15.74**	1.36	6.48*	21.10**	419.11**	719.31**	569.78**
Error	18	0.01	4.62	0.85	3.17	2.34	0.49	8.47	17.80	37.71

***Significant at 5% (p≤0.05) level of probability; ** Significant at 1% (p≤0.01) level of probability.**

Table 4 shows the combined mean squared revealing significant differences among the genotype of the ten varieties planted in all the characters studied at 1% (p≤ 0.01) probability. Table 4 also shows that for location, all the characters were significant at 1% (p≤ 0.01) probability.

Results obtained for Genotype and Location Interaction showed that the plant height, Number of leaves, Number of branches, Number of Flowers and Number of fruits were significant at 1% (p≤ 0.01) probability while fruit diameter was significant at 5% (p≤ 0.05).

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This study agrees a similar study which confirmed that there are a lot of tomato cultivars, and they vary a great deal in size, shape, colour, pulp content and growth requirement. (Adeleke and Minimah, 2017). This study agrees with another study by Ghanem, *et al*., (2009) that states that Tomato plants are adapted to a wide range of climate. A study by Ezekiel *et al* (2011) stated that "In Nigeria, eco-geographical differences have been used to determine the distribution of diversity in tomato crop". And this agrees with the present study.

Table 5 shows the combined effect of location of Analysis on nine vegetative and reproductive yield characteristics in ten varieties of tomato evaluated in Babcock University and IAR & T. There was a significant difference between each character between the varieties planted in Babcock and the varieties planted in IAR&T (Table 4.5). For plant height, Babcock (0.67) was significantly higher than IAR & T (0.58). For the number of leaves, it was 33.10 for Babcock and 28.73 for IAR & T; number of branches was 12.57 for Babcock and 6.70 for IAR & T; stem girth was 19.77 for Babcock and 12.99 for IAR & T; number of flowers was 17.17 for Babcock and 7.30 for IAR & T. For the number of fruit, it was 4.40 for IAR & T and 2.67 for Babcock; fruit diameter had 26.63 for IAR & T and 22.14 for Babcock; fruit length was 35.37 for IAR & T and 29.81 for Babcock and Fruit weight (19.70 for IAR & T and 14.07 for Babcock) were significantly higher in IAR & T than in Babcock.

Table 4: Combined mean squares of Analysis of Variance of nine Vegetative and Reproductive Yield Characteristics in ten varieties of tomato evaluated in Babcock University and IAR & T

VEGETATIVE REPRODUCTIVE

Source of variation	df	Plant_height	No_leaves	No_branches	Stem_girth	No_flower	No_fruits	Fruit_diameter	Fruit_length	Fruit_weight
Block (loc)	4	0.02*	5.02	0.47	1.38	4.27	0.77	45.94*	74.13	47.86
Genotype	9	0.10**	177.34**	8.07**	5.59**	33.3**	16.44**	678.09**	1171.94**	857.99**
Location	1	0.12**	286.02**	516.27**	690.95**	1460.27**	45.07**	302.18**	464.59**	475.59**
G x L	9	0.07**	252.28**	15.3**	2.92	37.04**	14.51**	33.62*	47.92	81.09
Error	36	0.01	4.17	1.21	1.67	2.12	0.45	15.78	40.68	65.16

***Significant at 5% (p≤0.05) level of probability; ** Significant at 1% (p≤0.01) level of probability**

Table 5: The combined effect of location on the nine Vegetative and Reproductive Yield Characteristics in ten varieties of tomato evaluated in Babcock University and IAR & T

VEGETATIVE REPRODUCTIVE

Location	Plant Height	Number of Leaves	Number of Branches	Stem Girth	Number of Flower	Number of Fruits	Fruit Diameter	Fruit Length	Fruit Weight
Babcock	0.67^a	33.10^a	12.57^a	19.77^a	17.17^a	2.67^b	22.14^b	29.81^b	14.07^b
Ibadan	0.58^b	28.73^b	6.70^b	12.99^b	7.30^b	4.40^a	26.63^a	35.37^a	19.70^a

Means with similar alphabets along the column were not statistically different (p≤0.05) level of probability

Table 6 and 7 shows the mean performance of all the varieties with respect to nine morphological traits in Babcock University and IAR & T. Plant height ranged from 0.55 m to 0.84 m with Roma VF and Rio Fuego recording the highest significant value whereas Yellow Pear recorded the lowest value (0.55

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cm). However, the number of leaves ranged from 26 to 46 leaves per plants, Rio Fuego had the highest significant number of leaves per plant (46) while Roma VF produced the least number of leaves (26 leaves). The varieties had a range of number of branches from 10 to 15 branches, with the highest significant number of branches also recorded by Rio Fuego while Roma VF, U C 82-B, Rio Grande, Roma Savanah and Hausa Local had significantly lower number of branches (11 - 12 branches per plant).

The stem girth ranged from 16.66 mm to 21.74 mm. The Roma Savannah variety had the significantly biggest stem girth, which was not be significantly different from values obtained from U C 82-B and Hausa Local while the Roma VF variety recorded the lowest significant value in stem girth (16.46 mm). Flower production on the varieties ranged from 11 flowers to 24 flowers, TROPIMECH produced significantly higher number of flowers while the least number of flowers was recorded in U C 82-B, Hausa Local and Red Cherry Tomato. Meanwhile, Red Cherry Tomato did not produce any fruit possibly due to unfavourable climatic condition. Fruit production ranged from 1 to 5 fruits with TROPIMECH recording a significantly highest number of fruits than other varieties. This is at variance with the report of Olaniyi *et al.*, (2010) showing that U C 82-B had a significantly higher growth and yield performance. This however might be attributed to genetic differences as postulated by Olaniyi and Fagbayide (1999).

For the yield data, the Roma Savanah produced a significantly better fruit in terms of diameter (33.81mm), length (43.55 mm) and weight (35.22 g) (Table 4.6). On the average overall performance in economic yield, Roma Savanah did better than the other varieties and can be used as a putative variety in tomato fruit yield improvement.

Table 6: Mean performance of 10 tomato varieties planted in Babcock University with respect to growth and yield characteristics

Genotype	Plant height (m)	No of leaves	No of branches	Stem girth (mm)	No of flower	No of fruits	Fruit diameter (mm)	Fruit length (mm)	Fruit weight (g)
ROMA VF	**0.84a**	26.33	11.00c	16.46d	19.00b	1.00d	27.91ac	38.66ab	14.46bcd
U C 82-B	0.72ab	29.00e	11.67c	**21.31a**	12.33d	1.00d	**29.44a**	37.57ab	25.25ab
RIO GRANDE	0.63bc	29.67e	11.67c	20.14b	15.00c	2.33c	17.97de	17.37c	2.94d
TROPIMECH	0.60bc	30.00e	**14.67a**	18.85c	**23.67a**	**5.00a**	24.10cd	36.85ab	15.29bcd
ROMA SAVANAH	0.61bc	38.33b	10.67c	**21.74a**	**22.67a**	4.67ab	**33.81a**	**43.55a**	**35.22a**
RIO FUEGO	**0.84a**	**46.33a**	**15.00a**	20.19b	19.00b	3.67b	20.17cde	23.56bc	6.12bcd
BEEFSTEAK	0.61bc	33.67cd	12.33bc	19.66b	15.67c	4.00ab	27.05ac	32.98ab	14.46cd
YELLOW PEAR	0.55c	32.33de	13.00abc	19.46bc	21.33ab	4.00ab	27.87ac	34.47ab	22.07abc
HAUSA LOCAL	0.64bc	29.33e	11.33c	**21.17a**	12.00d	1.00d	13.05	33.04ab	4.86cd
RED CHERRY TOMATO	0.70abc	36.00bc	14.33ab	18.74c	11.00d	0.00	0.00	0.00d	0.00d

Means with similar alphabets along the column were not statistically different ($p \leq 0.05$) level of probability

For varieties planted in IAR & T however, plant height ranged from 0.30 m to 1.07 m, TROPIMECH recorded the highest significant value among the ten varieties planted while Yellow Pear recorded the least significant value (0.30 m). Number of leaves ranged between 11 to 47 leaves, TROPIMECH recorded the highest significant number of leaves while Yellow Pear produced the least number of leaves. Number of branches ranged from 3 to 9 branches with TROPIMECH having the highest significant number of branches while Red Cherry tomato had a significantly lower number of branches per plant. The stem girth recorded ranged from 12.15 mm to 14 mm, however, Roma Savanah variety had the biggest stem girth which was not significantly different from the rest of the planted varieties. The number of flowers produced ranged from 5 to 9 flowers, Roma Savanah variety produced the

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most significant number of flowers and with the least numbers of flowers being from Beefsteak (5 flowers per plant). Red Cherry Tomato did not also produce fruits. This seems to suggest that Red Cherry may not be suitable for tomato fruit production in these locations because of unfavourable climatic factor or nutrient incompatibility factors which inhibits fruit development which inhibited flowers produced to become fruit. Since radiation is an important environmental factor for plants due to its direct or indirect impact on growth and development, perhaps Red Cherry may be more photo sensitive than other varieties. The adaptations by the plant photosynthetic apparatus in response to environmental lighting conditions reflect growth and fruiting; such morphophysiological responses of plants do not only depend on the presence, attenuation, or absence of light, but also on variations in light quality (Engel and Poggiani, 1991). The following five factors suggested by Bradshaw (2018), "blossom drop phenomenon", high humidity, poor air circulation and too many flowers can cause a tomato variety to flower but not fruit, these factors should be carefully guarded against. Fruit production across other varieties ranged from 1 to 8 fruits with the significantly highest number of fruit recorded by Hausa Local while Beefsteak recorded a significantly lowest number of fruits production. For the yield data, Roma Savanah produced a significantly bigger fruit in terms of diameter (38.80 mm), length (52.38 mm) and weight (40.89 g) (Table 7). In the average overall performance in economic yield, Roma Savanah did better than the other varieties and can be used as a putative variety in tomato fruit yield improvement.

Table 7: Mean performance of 10 tomato varieties planted in IAR&T with respect to growth and yield characteristics

Genotype	Plant height (m)	No of leaves	No of branches	Stem girth(mm)	No of flower	No of fruits	Fruit diameter (mm)	Fruit length (mm)	Fruit weigh (g)
ROMA VF	0.70b	31.00c	8.00ab	12.59a	9.00a	6.00bc	27.10d	37.15c	11.59de
U C 82-B	0.59bc	32.00c	8.33ab	13.45a	6.67abc	4.00d	37.29ab	46.87ab	30.38ab
RIO GRANDE	0.66b	40.33b	8.67ab	13.59a	7.00abc	5.00cd	18.80e	18.26d	4.69ef
TROPIMECH	**1.07a**	**47.33a**	**9.00a**	13.15a	7.33abc	4.67d	29.61cd	40.66bc	18.57cd
ROMA SAVANAH	0.50cd	27.00d	8.33ab	**13.61a**	**9.00a**	6.33b	**38.80a**	**52.38a**	**40.89a**
RIO FUEGO	0.66b	28.67cd	7.00b	14.09a	5.67bc	7.00ab	33.15bc	38.42d	27.76bc
BEEFSTEAK	0.50cd	31.00c	4.00c	12.28a	5.33c	1.00ef	25.85d	34.26c	15.72de
YELLOW PEAR	0.30e	11.67f	4.00c	12.15a	5.67bc	2.00e	37.04ab	47.26ab	36.98ab
HAUSA LOCAL	0.43de	19.00e	7.00b	12.51a	9.00a	**8.00a**	18.61e	38.45c	10.39def
RED CHERRY TOMATO	0.41ed	19.33e	2.67c	12.44a	8.33ab	0.00f	0.00f	0.00e	0.00f

Means with similar alphabets along the column were not statistically different ($p \leq 0.05$) level of probability

The combined mean performance of all ten varieties in nine morphological traits in Babcock University and IAR &T are shown in Table 8 In terms of growth of the plants, plant height ranged from 0.43 m to 0.84 m with TROPIMECH recording the highest significant value whereas Yellow Pear recorded the lowest value (0.43 m). Also, using the number of leaves indices, the number of leaves ranged from 22 to 38 leaves per plants, TROPIMECH had the most significant numbers of leaves per plant while Yellow Pear produced the least number of leaves (22 leaves). Number of branches among the varieties ranged from 8 to 11 branches, with the most significant number of branches also recorded by TROPIMECH while Beefsteak, Yellow Pear and Red Cherry Tomato had significantly lower number of branches (8 branches per plant). The stem girth ranged from 14.53 mm to 17.67 mm, the Roma Savannah variety had the significantly biggest stem girth, while Roma VF variety recorded the lowest significant value in stem girth (14.53 mm). Flower production on the varieties ranged from 10 flowers to 16 flowers, Roma Savannah variety produced significantly higher number of flowers while the least number of

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flowers was significantly recorded in U C 82-B and Red Cherry Tomato. Meanwhile, Red Cherry Tomato, however, did not produce fruits possibly due to unfavourable climatic condition and other abiotic and biotic conditions. Fruit production ranged from 2 fruit to 5 fruits with Roma Savannah recording a significantly higher number of fruits than other varieties (Table 8).

For the yield data, the Roma Savanah produced a significantly better fruit in terms of diameter (36.31 mm), length (47.97 mm) and weight (38.05 g) (Table 4.2). On the average overall performance in economic yield, Roma Savanah did better than the other varieties and can be used as a putative variety in tomato fruit yield improvement.

Table 8: Combined Mean performance of Ten Varieties of Tomato in Growth and Yield Traits

Genotype	Plant Height (m)	No of leaves	No of branches	Stem Girth (mm)	No of flower	No of fruits	Fruit Diameter (mm)	Fruit Length (mm)	Fruit Weight (g)
ROMA VF	0.77a	28.67de	9.50cd	14.53d	14.00bc	3.50c	27.50b	37.91bcd	13.02cd
U C 82-B	0.66bc	30.50cd	10.00bc	17.38ab	9.50e	2.50d	33.37a	42.22ab	27.81b
RIO GRANDE	0.64c	35.00b	10.17bc	16.86abc	11.00de	3.67c	18.38c	17.81e	3.81de
TROPIMECH	**0.84a**	**38.67a**	**11.83a**	16.00abcd	15.50ab	4.83ab	26.86b	38.75bcd	16.93c
ROMA SAVANAH	0.56cd	32.67bc	9.50cd	**17.67a**	**15.83a**	**5.50a**	**36.31a**	**47.97a**	**38.05a**
RIO FUEGO	0.75ab	37.50a	11.00ab	17.14abc	12.33cd	5.33a	26.66b	30.99d	16.94c
BEEFSTEAK	0.56cd	32.33c	8.17d	15.97abcd	10.50de	2.50d	26.45b	33.62cd	15.09c
YELLOW PEAR	0.43e	22.00f	8.50d	15.81bcd	13.50c	3.00cd	32.46a	40.86abc	29.52ab
HAUSA LOCAL	0.54d	24.17f	9.17cd	16.84abc	10.50de	4.50b	15.83c	35.75bcd	7.63cde
RED CHERRY TOMATO	0.55cd	27.67e	8.50d	15.59cd	9.67e	0.00e	0.00d	0.00f	0.00e

Means with similar alphabets along the column were not statistically different (p≤0.05) level of probability

Phenotypic and Genotypic correlation coefficients between varieties of tomato and yield characteristics in Babcock University are illustrated in Table 9. Plant height was strongly negatively correlated at phenotypic (P ≤ 0.05) and genotypic (P ≤ 0.01) levels with number of fruits (-0.47, -0.59). This is at variance with some other studies by Ara *et al*. (2009), Ahiwar *et al.* (2013) and Sharma and Jaipaul (2014), that found out that plant height at genotypic and phenotypic levels was strongly positively correlated with number of fruits. This could be as a result of abiotic and biotic factors, such as the climatic zones in which the experiment was conducted and further factors like the soil flora and funa. Plant height had a strong negative correlation at genotypic level with fruit length (-0.39) at probability of 0.05% and with fruit weight (-0.60) at probability of 0.01%. From this result, it is obvious that plant height predicts lower fruit production and smaller fruits; this might be attributed to competition for nutrients which may reduce the plants ability to produce fruits.

Number of leaves was strongly positively correlated at phenotypic (P ≤ 0.05) and at genotypic (P ≤0.01) levels with number of branches (0.48, 0.59) and with number of fruits (0.53, 0.56). From this result, it can be inferred that number of leaves on the plants could be used to predict both branch.

Number of branches had positive correlation at both phenotypic and genotypic level with number of flowers (0.39, 0.43) at a probability of 0.05% and also with number of fruits at phenotypic level (0.53) at a probability of 0.05% and at the genotypic level (0.51) at a probability of 0.01%. However, there was a negative correlation at genotypic level at a probability of 0.05% with fruit length (-0.44) and weight (-0.41). This result indicates that number of branches could be a predictor of number of flowers and fruits on the plants, however selection on the basis of number branches may not favour fruit length.

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There was no significant correlation between the stem girth of the plants and other variables. The number of flower was strongly positively correlated at phenotypic and genotypic levels (P ≤0.05; P ≤0.01) with number of fruits (P ≤0.01) (0.77, 0.80); with fruit diameter (P ≤0.05; P ≤0.01) (0.47, 0.53); with fruit length (0.43) at genotypic level at probability level of 0.05% and with fruit weight (0.42, 0.49) at probability of 0.05%. This indicates that the number of flowers produced by a tomato plant predicts the number of fruits, fruit diameter, length and weight (Tables 9 and 6).

The number of fruits was positively correlated at only the genotypic level at a probability of 0.05% with fruit diameter (0.40) and with fruit weight (0.39). This result revealed that number of fruits per plant could be used to predict the diameter and weight of the fruits. The fruit diameter was strongly positively correlated at both phenotypic and genotypic levels at a probability of 0.01% with fruit length (0.69, 0.64) and with fruit weight (0.90, 0.91) (P ≤0.01). Also, fruit length was strongly positively correlated at phenotypic and genotypic levels at a probability of 0.01% with fruit weight (0.80, 0.73). Findings from this study is similar to other studies assessing path correlation between variables, Lakshmi and Mani (2004), Singh and Cheema (2005) and Haydar *et al*. (2007) opined that fruit weight per plant exerted high positive and direct effect on fruit yield. Crop improvement programme largely depends on availability of sufficient variability and association among different characters which are the pre-requisite for executing an effective selection programme. The correlation studies are one of the tools which help in measuring the degree and magnitude of association between two characters. The breeding programme is considered to be most effective if it is concentrated towards one or at the most few characters. The knowledge of correlation between different characters that exhibit low heritability and gives information regarding the nature, extent and direction of selection pressure among the characters. Yield is considered to be a complex, polygenic and highly variable character determined by cumulative effects of its component characters. Adam and Grafius (1971) have mentioned that yield should be considered as an end product of number of characters and breeder should not ignore the principle of balance among these components. Therefore, direct selection for yield may not be very effective and precise. Thus, it becomes necessary to find out the direction and degree of association between two characters at phenotypic and genotypic levels. Various characters under study may have an association with each other and may affect the total yield per plant.

Table 9: Phenotypic and Genotypic correlation coefficients between growth and yield characteristics of 10 tomato varieties in Babcock University.

Character	No of leaves	No of branches	Stem girth	No of flowers	No of fruits	Fruit diameter	Fruit length	Fruit weight
Plant height (P)	0.22	0.09	-0.36	-0.16	-0.47*	-0.08	-0.13	-0.27
(G)	0.28	0.04	-0.38	-0.22	-0.59**	-0.25	-0.39*	-0.60**
No leaves (P)		0.48*	0.37	0.31	0.53*	0.04	-0.22	0.05
(G)		0.59**	0.38	0.33	0.56**	0.06	-0.26	0.09
No branches (P)			-0.14	0.39*	0.53*	-0.22	-0.33	-0.31
(G)			-0.14	0.43*	0.51**	-0.24	-0.44*	-0.41*
Stem girth (P)				-0.32	0.09	-0.08	-0.05	0.24
(G)				-0.31	0.10	-0.08	-0.06	0.30
No flower (P)					0.77**	0.47*	0.34	0.42*
(G)					0.80**	0.53**	0.43*	0.49*
No fruits (P)						0.33	0.10	0.32
(G)						0.40*	0.12	0.39*
Fruit diameter (P)							0.69**	0.90**
(G)							0.64**	0.91**
Fruit length (P)								0.80**
(G)								0.75**

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Phenotypic and Genotypic correlation coefficients between varieties of tomato and yield characteristics in IAR & T are illustrated in Table 10. Plant height was strongly positively correlated at phenotypic and genotypic levels at probability of 0.01% with number of leaves (0.90, 0.94) and with number of branches (0.66, 0.69). This result indicates that plant height is a strong predictor for number of leaves and number of branches produced by the plant, (Table 10)

Number of leaves was positively correlated at both phenotypic and genotypic level with the number of branches (0.65, 0.70) (P ≤0.01). Further, number of leaves had a strong negative correlation at phenotypic and genotypic levels (P ≤0.05) with fruit length (-0.44, -0.46) and with fruit weight (-0.42, -0.46). From this result, it is obvious that number of leaves predicts the number of branches, and smaller fruits.

Number of branches was positive correlated at phenotypic and genotypic levels at a probability level of 0.01% with number of flowers (0.59, 0.67); fruits (0.63, 0.64) and with stem girth at the phenotypic level (0.42) and at genotypic level (0.57) at a probability of 0.05% and 0.01% respectively. This showed that number of branches predicts increased flower and fruits production and also bigger stem girth in the plants.

The stem girth was positively correlated at the genotypic level at a probability level of 0.05% with number of fruits, indicating that the stem girth of plants predicts the production of fruits.

Number of flower was strongly positively correlated at both phenotypic and genotypic levels at a probability of 0.01% with number of fruits (0.69, 0.81). This result indicates that number of flowers predict the number of fruit production in plant in IAR&T.

The fruit diameter was strongly positively correlated at both phenotypic and genotypic levels at a probability of 0.01% with fruit weight (0.95, 0.96) and with fruit length (0.83) at genotypic level at a probability level of 0.01%. Also, fruit length was strongly positively correlated at phenotypic and genotypic levels (P ≤0.01) with fruit weight (0.86, 0.86). This finding was similar to that of Bodunde (2002) who reported that plant height, fruit diameter and fruit length was directly responsible for the determination of fruit yield in tomato.

Table 10: Phenotypic and Genotypic correlation+n coefficients between varieties of tomato and yield characteristics in IAR&T

Character	No of leaves	No of branches	Stem girth	No of flower	No of fruits	Fruit diameter	Fruit length	Fruit weight
Plant height (P)	0.90**	0.66**	0.25	0.12	0.18	-0.12	-0.23	-0.32
(G)	0.94**	0.69**	0.34	0.16	0.19	-0.14	-0.27	-0.37
No leaves (P)		0.65**	0.29	0.03	0.02	-0.23	-0.44*	-0.42*
(G)		0.70**	0.28	0.06	0.04	-0.25	-0.46*	-0.46*
No branches (P)			0.42*	0.59**	0.63**	-0.08	-0.11	-0.19
(G)			0.75**	0.67**	0.64**	-0.08	-0.12	-0.20
Stem girth (P)				0.01	0.31	0.14	-0.04	0.12
(G)				0.15	0.53*	0.17	-0.10	0.10
No flower (P)					0.69**	-0.21	0.14	-0.18
(G)					0.81**	-0.26	0.18	-0.24
No fruits (P)						-0.22	0.00	-0.15
(G)						-0.22	0.00	-0.15
Fruit diameter (P)							0.83	0.95**
(G)							0.83**	0.96**
Fruit length (P)								0.86**
(G)								0.86**

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Mean estimates of genotypic and phenotypic variance, phenotypic and genotypic coefficient of variability, broad sense heritability and genetic advance expressed as percentage mean at the Babcock site are presented in Table 11. Phenotypic variances were obviously higher than the genotypic variances in the nine characters studied. This is expected since phenotypic variance was a sum of genotypic and environmental variance. Genotypic variance was found to be higher than environmental variance in all the characters studied at Babcock University, this points to the fact that all the characters were more under influence of the genotype, this points to the conclusion that any selection on the basis of the phenotype may prove positive in the improvement of these characters because the phenotype we are seeing is backed by genes and not environmental effects. Similar observations have been reported by earlier researchers Nwangburuka *et al.,* (2011) in okra and Al-Fraihat *et al* (2011) reporting on yield components in barley.

Heritability estimates along with Genetic Advance (GA) are normally more helpful in predicting the plant under selection than heritability estimates alone. The knowledge of heritability along with genetic advance aid in drawing valuable conclusions for effective selection based on phenotypic performance. Therefore, the estimation of heritability for any trait requires the partitioning of observed variation between genetic effects (Cockerham, 1963). However, when the phenotypic variability is large, traits with high heritability values are subject to large genetic gains per generation when selection is applied (Falconer 1989). When high estimates of GCV, Heritability, and Genetic advance (GA) are observed, it is safe to say that the particular trait is a reliable selection predictor for vegetative and seed yield (Nwangburuka *et al.,* 2014) and Shepra *et al*. (2014).

Fruit weight obtained the highest phenotypic and genotypic variances at 111.01 and 76.53 respectively, whereas the lowest in phenotypic and genotypic variances were observed in plant height at 0.01 and 0.01 respectively. The high genotypic variance observed in all the characters above the environmental variance suggests that all the characters under study were more influenced by the genotype, reinforcing the reliability of selection based on phenotype for crop improvement. The phenotypic coefficient of variation (PCV) generally ranged between 0.00 for plant height and 2.52 for the fruit length. The slight variation between values

Table 11: Mean Estimates of Genotypic and Phenotypic Variance, Phenotypic and Genotypic Coefficient of Variability, Broadsense Heritability and Genetic Advance expressed in nine Vegetative Yield Characteristics in ten varieties of tomato evaluated in Babcock University

Character	Phenotypic variation	Genetic variation	Environmental Variability	PCV	GCV	Heritability	Genetic advance
Plant_height	0.01	0.01	0.00	0.00	0.00	79.41	25.95
No_leaves	37.58	36.19	1.39	2.02	1.98	96.30	36.89
No_branches	2.43	1.85	0.58	0.19	0.16	76.25	20.50
Stem_girth	2.53	2.47	0.06	0.30	0.30	97.45	16.94
No_flower	18.67	17.97	0.70	0.68	0.67	96.24	54.11
No_fruits	2.71	2.55	0.16	0.05	0.05	94.24	106.46
Fruit_diameter	41.66	33.07	8.60	1.51	1.35	79.37	45.05
Fruit_length	64.33	40.90	23.43	2.52	2.01	63.58	33.49
Fruit_weight	111.01	76.53	34.48	1.55	1.29	68.94	101.46

PCV and GCV among all the characters studied suggests that these characters are under genetic control. General heritability in the broadsense estimate was high amongst all the characters studied as suggested by Dabhalker, (1996). The broadsense heritability ranged from 63.58 in fruit length to 97.45 in stem girth. This suggests that all the characters are under the control of additive genes and therefore selection on the basis of the phenotype will lead to improvement in yield. High broadsense heritability estimates have been reported on some vegetative characters of other vegetable crops

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such as *Telfairia* (Aremu & Adewale, 2012). Yield predictions is most reliable when done on the basis of joint combinations of high GCV, Heritability and GA than when done on the basis of GCV and /or heritability alone (Murtadha *et al.,* 2004). For instance characters such as fruit length, number of leaves among others combining high GCV, Heritability, and High Genetic Advance are reliable predictors of yield. Thus selection that is based on the phenotypic expression of all the characters studied will ultimately result in yield improvement. This was also observed by Ogunbayo *et al.,* (2009), in rice.

Mean estimates of genotypic and phenotypic variance, phenotypic and genotypic coefficient of variability, broadsense heritability and genetic advance expressed as percentage mean at IAR & T are presented in Table 12.

Phenotypic variances measured were found to be higher than the genotypic variances measured, this trend was found to be similar in the nine characters studied at IAR&T. This trend is what is normally expected since phenotypic variance is an addition of genotypic variance plus environmental variance. It was observed that genotypic variance is higher than environmental variance in all the characters studied at IAR&T. This may suggest that all the characters were more under genotypic influence and therefore selection on the basis of the phenotype may give a positive improvement of these characters. Similar observations have been reported by Manggoel *et al.,* (2012) in cowpea.

Heritability estimates in combination with Genetic Advance (GA) normally gives a more precise insight in predicting the plant under selection than heritability estimates alone. Thus, the estimation of heritability for any trait requires the partitioning of observed variation between genetic effects (Cockerham, 1963). However, when the phenotypic variability is large, traits with high heritability values are subject to large genetic gains per generation when selection is applied (Nyquist, 1991). When high estimates of GCV, Heritability, and GA are observed, it is clear and can be expressed by saying that a particular trait is a reliable selection predictor for vegetative and seed yield (Nwangburuka *et al.,* 2014, Bello *et al.,* 2006). We can conclude that, because these traits have high GCV and heritability, improvement that is directed to these characters will result in an improvement in vegetative and seed yield.

General heritability in the broadsense estimate varied from 59.37 for stem girth to 98.47 for number of leaves. Genetic advance (GA) also had a largely varied range which was between 10.13 for stem girth and 120.66 for fruit weight. This suggests that majority of the traits studied in the field were more under the influence of the genetic factor so selection can be done based on morphological expressions alone.

CONCLUSION

Growth parameters varied across the 10 varieties of tomatoes planted, however, TROPIMECH variety grew the tallest with the most number of leaves and branches. Plant height was strongly negatively correlated at phenotypic and genotypic levels with fruit yields and fruit length at Babcock University, suggesting that any selection directed towards plant height may not produce a positive effect on number of fruits and fruit length. This results also suggests that selections directed towards number of leaves may lead to fruit yield at locations similar to Babcock University. Selection of plants based on number of branches can predict high fruit yield successfully. Furthermore, this indicates that the number of flowers produced by a tomato plant could be a veritable index in predicting the number of fruits, fruit diameter, length and weight. Additionally, this result revealed that number of fruits produced predicts the diameter and weight of the fruits.

Phenotypic variances were higher than the genotypic variances in the nine characters studied. This is expected since phenotypic variance is a sum of genotypic and environmental variance. Meanwhile

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genotypic variance was higher than environmental variance in all the characters studied at Babcock, this may suggest that all the characters were more under genotypic influence and therefore selection on the basis of the phenotype may prove positive in the improvement of these characters. The data observed at IAR&T followed the same trend like the data collected from Babcock site in respect to estimates of phenotypic and genotypic variances, phenotypic and genotypic coefficients of variability, broadsense heritability and genetic advance.

All the traits studied were under additive gene action since all exhibited high heritability and genetic advance and improvement could be achieved from selection based on morphological observations.

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