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Variation among five accessions of tomato [Solanum lycopersicum (L.) H. Karst] for crossability

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Abstract – One of the strategies to bring about genetic improvement in a crop is to create genetic variability through hybridization. The present study assessed the level of crossability among five accessions of tomato using the reciprocal crossing technique. The accessions were grown in plastic pots in the screen house and at maturity; hybridizations were manually performed between 7.00 and 10.00 am on crossing days. Significant differences were observed among the crosses for traits such as the number of flowers crossed, number of successful crosses, percentage of successful crosses, average fruit weight per cross, and average fruit yield. Generally, 139 successful fruits were generated from a total of 336 crosses amounting to a 41.37% success rate which implies a less-than-average level of cross-compatibility among the accessions. The number of flowers had a high positive correlation with the number of successful crosses (0.82) and fruit yield per cross (0.76). The number of successful crosses was highly positively correlated with the percentage of successful crosses (0.58) and the fruit yield per cross (0.94). Also, the percentage of successful crosses was highly positively correlated with fruit yield per cross (0.59) while the average fruit weight per cross was highly positively correlated with both fruit yield per cross (0.59) and pericarp thickness of fruits (0.51). The results indicated that genotypes having a higher capacity for flowering are more desirable for hybridization due to their propensity for producing a higher success rate of crosses as well as a higher yield among crosses.

Keywords – Correlation, flowers, hybridization, maternal parent, yield

I. Introduction

Tomato is the world's most consumed vegetable due to its status as a basic ingredient in a large variety of raw, cooked, or processed foods. It belongs to the family Solanaceae which includes several other commercially important species [1], [2]. This crop has become widely grown worldwide because of its important characteristics such as wider adaptability, suitability for a diversity of uses in fresh and processed foods, and high-yielding potential [3]. Also, the lycopene (red pigment) contained in tomato is considered one of the world's most powerful antioxidants [3]. These attributes are the reasons the present global demands have exceeded production [4].

Tomato is a good source of vitamin C and lycopene. The fruit can be processed into different products such as puree, ketchup, and juice, also it can be eaten raw in a salad, cook in a sauce, or as a raw material for food processing in food industries [5]. It is a fruit of good nutritive value as it is fairly rich in vitamins and other minerals like calcium, phosphorus, and iron considering its low cost, it qualifies for inclusion in the daily diet of young and growing children [6].

In Nigeria, the cultivation of tomatoes has been for ages and is predominantly done in the northern part of the country, although it does well in all the Nigerian agro-ecological zones [7], [8]. In 2018, Nigeria was ranked the 13th largest tomato-producing country in the world with the potential to top the highest-producing countries in terms of production and export [2], [9]. Unfortunately, one of the major factors keeping Nigeria from the top position is the low productivity of the available cultivars and the high level of susceptibility to diseases and pests. The average yield in Nigeria is between 15 to 30 tonnes per hectare compared to more than 100 tonnes per hectare in the Netherlands and other countries, leading to the yearly production of about 1.8 million tonnes as against the local demands of about 2.4 million tonnes [7]. The low productivity of tomato is majorly a consequence of the narrow genetic base of the available cultivars and also from genetic erosion imposed on the crop in the process of domestication due to rigorous selection of a few desired traits leading to loss of genetic diversity [10], [11], [12], [13]. Therefore, there is a need for a breeding program that can circumvent the problem of limited genetic diversity to allow an increase in tomato productivity in Nigeria.

One of the simple strategies to bring about genetic improvement to a crop is to create genetic variability through hybridization. Hybrids have been found to offer several advantages such as higher productivity, earliness, better quality, and enhanced resistance to both biotic and abiotic constraints compared to parental lines [14]. Although, considerable number of work have reported the importance of hybridization in the improvement of tomatoes in many countries [15] by exploiting the diversity of different fruit traits [11]. However, proper attention to tomato improvement in Nigeria is lacking [16]. Hence, exceptional measures are needed to expand the genetic diversity of the crop in Nigeria. Hybridization is the natural or artificial process of producing hybrids by crossing two individuals from different populations that are genetically different [17]. This process does not change the genetic content of organisms but rather produces new combinations of genes that could have certain desirable characteristics or phenotypes.

The objective of the present study was to assess the level of crossability among five accessions of tomato using the reciprocal crossing technique. The accessions involved in the study were previously selected based on high yield and other important characteristics as reported in Gbadamosi *et al.* (2020). So, the key here was to cross the high-yielding tomatoes to produce promising genotypes with improved yield, adaptability, and quality and disease resistance.

II. Materials and Method

Collection of samples and experimental site

The five accessions of tomato used for the study are presented in Table 1. These accessions were collected originally from the National Centre for Genetic Resources and Biotechnology (NACGRAB), Ibadan, and Akungba-Akoko, and selected based on performance in a previous study [2]. The study was conducted at the screen house, Department of the Plant Science and Biotechnology, Adekunle Ajasin University, Akungba - Akoko, Nigeria, between March and July 2020.

Experimental procedure

The seeds of accessions were sown in labeled baskets filled with topsoil and the emerging seedlings were raised in the nursery for three weeks while being watered daily.

Crosses were done following [14] with a few modifications. Two seedlings from each accession were transplanted in plastic pots filled with 7.5 kg topsoil after three weeks in the nursery. Ten pots were used for each accession arranged in two rows for direct crosses and their reciprocals. Five pots from each cross contained the pollen receptors (maternal parents) while the remaining five contained the pollen donors, and each pot was watered to field capacity every other day. As flowers mature, emasculation and manual pollination were performed in the morning (between 7 and 10.00 am). Afterward, hybridized flowers were tagged and properly labeled with dates and hybridization types. Successfully pollinated flowers were visible within one week of pollination. Pollination persisted until flowering terminated for all plants in the screen house.

Data collection

The data collected include the number of flowers pollinated, number of successful crosses, percentage of successful crosses, average fruit weight from crosses, fruit yield per cross, and number of locules per fruit per cross. Summary statistics and correlation analysis of data were done with the paleontological statistical package (PAST 4.01).

Table 1. List of accessions of tomato

Accession ID	Accession source	Origin	Biological status
NGSA0110002	NACGRAB	Republic of Benin	Landrace
NGB01357	NACGRAB	Unknown	Landrace
NGAASEP09042	NACGRAB	Southwest, Nigeria	Landrace
NGB01371	NACGRAB	Unknown	Landrace
Akungba-1	Akungba-Akoko	Southwest, Nigeria	Landrace

III. RESULTS AND DISCUSSION

The obtained results among the crosses are presented in Table 2. Significant differences were observed among the crosses for all traits. The number of flowers pollinated was influenced by the capacity of each accession to produce a higher number of flowers. For instance, most direct crosses had a higher number of flowers ready to be pollinated by the pollen receptor compared to their reciprocals. A similar result was reported by [18]. The coefficient of variation among traits was very high in traits such as the number of flowers crossed (52.56%), the number of successful crosses (80.52%), the percentage of successful crosses (43.47%), and average fruit weight (43.89%), and the average fruit yield (96.37%) suggesting a high level of variability for crossability among the accessions. The current study suggested that observed variations could be a consequence of high disparity in genetic architecture among the tomato genotypes, environmental factors, and interaction between genotype and environment (gei) as reported by [19].

The total number of flowers crossed between accessions ranged from the lowest (5) in NGB01371 × NGB01357 to the highest (35) in Akungba-1 × NGB01371. However, NGSA0110002 × NGAASEP09042 had the highest number of successful crosses (22) and the highest fruit yield (366.74 g), and also shared the highest average fruit weight (16.67 g) with NGSA0110002 × Akungba-1. The percentage of successful crosses ranged between 15.00% in NGAASEP09042 × NGSA0110002 and 81.82% in Akungba-1 × NGSA0110002. The cross NGAASEP09042 × NGSA0110002 was the poorest for the number of successful crosses (3), average fruit weight (3.33 g), and average fruit yield (9.99 g), and also shared the lowest pericarp thickness (2.67 mm) with NGSA0110002 × NGB01357 and Akungba-1 × NGAASEP09042, nonetheless. However, pericarp thickness was the highest (3.80 mm) in NGB01371 × Akungba-1 while the number of locules per fruit ranged between the lowest (2.00) amongst NGSA0110002 × NGB01357, NGB01371 × NGB01357, NGB01357 × Akungba-1 and the highest (3.50) in NGAASEP09042 × NGB01357.

Generally, 139 successful fruits were generated from a total of 336 crosses amounting to a 41.37% success rate which implies a less-than-average level of cross-compatibility among the accessions. According to [20], incompatibility can result from the failure of pollens to stay attached to the stigma or pollen tubes trapped in the upper or lower part of the style, a phenomenon regarded as incompatibility between pollen or pollen tubes of pollen donor and the pistil of the female plant [21], [22] or as a result of intraspecific self-incompatibility [23]. Damages caused by emasculation can also affect the level of crossability in tomatoes [19]. Similar levels of low compatibility among inter-specific and intra-specific crosses have been reported in tomatoes [14], [19]. Selection of tomato genotypes with high general crossability and avoiding poorly crossable genotypes can improve the efficiency of introgressing desirable genes in tomato hybrids. Hence, breeders must choose genotypes that are consistent in compatibility under prevailing environmental conditions [10]. In this regard, the crosses NGSA0110002 × NGAASEP09042 and Akungba-1 × NGSA0110002 with the highest success rates would contribute more positively to the breeding of the crop under the focused environment. Different success rates obtained among the direct crosses and their reciprocals indicated maternal influence on the crosses as reported in crosses of other crops such as cowpea [24], cowpea × mung bean [25], and sesame [26]. Furthermore, all crosses observed produced fruits and seeds. However, this result contradicts the findings of [20] who reported that out of 39 cross combinations, 5 produced no fruits and subsequently no seeds. The number of successful crosses depended on the number of available flowers, which influenced the number of fruit obtained. However, in the crosses, NGAASEP09042 × NGSA011002 which had a high number of flowers, the percentage of successful crosses was one of the lowest. This indicated that the level of compatibility between these accessions was low. Martins [22] reported a similar result.

The results for Pearson correlation are presented in Table 3. The number of flowers crossed was highly positively correlated with the number of successful crosses (0.82) and fruit yield per cross (0.76). The number of successful crosses was highly positively correlated with the percentage of successful crosses (0.58) and the fruit yield per cross (0.94). Also, the percentage of successful crosses was highly positively correlated with fruit yield per cross (0.59) while the average fruit weight per cross was highly positively correlated with both fruit yield per cross (0.59) and pericarp thickness of fruits (0.51). However, the number of locules per fruit did not correlate with any of the crossing data. The present results indicated that the number of successful crosses as well as fruit yield is directly related to the capacity of the genotype to produce a higher number of flowers. While the percentage of successful crosses had no bearing on the number of flowers available; it had a positive influence on the fruit yield of each cross in tomato. In the present study, all crosses observed produced fruits and seeds. The number of successful crosses depended on the number of available flowers, which influenced the number of fruits obtained and the fruit yield. However, in the crosses, NGAASEP09042 × NGSA011002 which had a high number of flowers, the percentage of successful crosses was one of the lowest. This indicated that the level of compatibility between these accessions was low. Martins [22] reported a similar result. Therefore, the selection of genotypes with the capacity to produce exceptionally high amounts of flowers would contribute positively to the breeding program of tomatoes.

Table 2. Level of crossability among five accessions of tomato

CROSS	NFC	NSC	PSC	AFW (g)	FYC (g)	PTF (mm)	NLF
NGSA0110002 × NGB01357	20	5	25.00	7.50	37.50	2.67	2.00
NGB01357 × NGSA0110002	15	4	26.67	6.67	26.68	3.00	2.25
NGSA0110002 × NGAASEP09042	34	22	64.71	16.67	366.74	3.60	2.90
NGAASEP09042 × NGSA0110002	20	3	15.00	3.33	9.99	2.67	2.67
NGSA0110002 × NGB01371	18	10	55.56	8.75	87.50	2.90	2.40
NGB01371 × NGSA0110002	33	14	42.42	20.00	280.00	3.00	2.40
NGSA0110002 × Akungba-1	14	3	21.43	16.67	50.00	3.30	3.00
Akungba-1 × NGSA0110002	11	9	81.82	20.00	180.00	3.20	2.50
NGB01357 ×NGAASEP09042	16	6	37.50	18.00	108.00	3.00	2.40
NGAASEP09042 × NGB01357	6	2	33.33	8.00	16.00	3.50	3.50
NGB01357 × NGB01371	13	4	30.77	10.00	40.00	3.40	2.60
NGB01371 × NGB01357	5	2	40.00	5.00	10.00	3.00	2.00
NGB01357 × Akungba-1	15	6	40.00	20.00	120.00	3.00	2.00
Akungba-1 × NGB01357	10	6	60.00	22.00	132.00	3.50	2.40
NGAASEP09042 × NGB01371	8	5	62.50	12.50	62.50	3.00	3.00
NGB01371 × NGAASEP09042	15	5	33.33	15.00	75.00	3.33	3.00
NGAASEP09042 × Akungba-1	11	5	45.46	10.00	50.00	3.00	3.33

Akungba-1 × NGAASEP09042	12	3	25.00	10.00	30.00	2.67	2.67
NGB01371 × Akungba-1	25	5	20.00	20.00	100.00	3.80	2.60
Akungba-1 × NGB01371	35	20	57.14	12.50	250.00	3.10	3.10
Mean	16.8	6.95	40.88	13.13	101.59	3.13	2.63
Standard deviation	8.83	5.59	17.77	5.76	97.9	0.32	0.43
Coefficient variation (%)	52.56	80.52	43.47	43.89	96.37	10.09	16.33

NFC: Number of flowers crossed; NSC: Number of successful crosses; PSC: Percentage of successful crosses; AFW: Average fruit weight of crosses; FYC: Fruit yield of crosses; PTF: Pericarp thickness per fruit; NLF: Number of locule fruit.

Table 3. Pearson correlation coefficient for crossing parameters among five accessions of tomato

Trait	NFC	NSC	PSC	AFW	FYC	PTF	NLF
NFC	1	0.82**	0.05	0.25	0.76**	0.09	0.004
NSC		1	0.58**	0.34	0.94**	0.18	0.12
PSC			1	0.39	0.59**	0.17	0.08
AFW				1	0.59**	0.51**	-0.06
FYC					1	0.32	0.05
PTF						1	0.34
NLF							1

NFC: Number of flowers crossed; NSC: Number of successful crosses; PSC: Percentage of successful crosses; AFW: Average fruit weight of crosses; FYC: Fruit yield of crosses; PTF: Pericarp thickness per fruit; NLF: Number of locules per fruit.

IV. CONCLUSION

A high level of variability existed among accessions for crossability which could be a consequence of disparity in genetic architecture, environmental factors, and interaction between genotype and environment (gei). The selection of genotypes for crosses should focus more on genotypes with higher crossable potentials for a successful breeding program of tomatoes. Genotypes having a higher capacity for flowering are more desirable for hybridization for their propensity for producing a higher success rate of crosses as well as a higher yield among crosses.

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