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IDENTIFICATION OF BETTER PARENTS FOR QUALITY AND YIELD ATTRIBUTING TRAITS IN TOMATO USING LINE × TESTER ANALYSIS

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Abstract *The production of tomato (Solanum lycopersicum L.) is hampered by postharvest losses, a major issue. Various methods have been employed to increase tomatoes' quality, yield, and shelf life, and ripening mutants is one of them. In 2019, an investigation was conducted at the Experimental Farm of the Vegetable Research Institute, Faisalabad, to explore tomatoes' combining ability and heterosis through a line x tester cross. This research aimed to create nine hybrids by crossing commercially grown tomato varieties (Nagina, Lyp. No. 1, and H-24) with ripening tomato mutants (88512, Titano, and Pakit) using the Line × Tester mating design. When stored one of the hybrids (88512 x H-24) showed an extended shelf life of up to 40 days. Analysis of variance indicated that non-additive gene action was predominant in all traits, with significant differences between parents and hybrids in terms of GCA and SCA effects. '88512' and 'H-24' were the best general combiners for fruit-keeping quality, and they may be used as donors in breeding programs. The cross between '88512' and 'H-24' was identified as a valuable combiner for improving postharvest shelf life in tomato breeding programs. The crosses '88512 × H-24' and 'Pakit × H-24' exhibited the highest heterotic effects for fruit-keeping quality and yield per plant, respectively. The mean values of genetic parameters in parents and F1 showed that the cross between 'H-24' and the ripening mutant '88512' resulted in high shelf life and good fruit quality*.

Keywords: *Tomato; GCA; SCA; Heterosis*

Introduction

Tomato is an economically important crop widely cultivated for its nutritional and commercial value. Each year, tomato (*Solanum lycopersicum L.*) crops yield around 182.3 million tons of fruit on 4.85 million hectares, making it the second most significant crop after potato among fruits and vegetables (FAOSTAT, 2019). Global tomato production is primarily dominated by Asia, accounting for 61.1% of the total yield, whereas Europe, America, and Africa contributed 13.5%, 13.4%, and 11.8% of the overall tomato output, respectively (FAOSTAT,2019). Tomatoes are rich in minerals such as vitamin A, vitamin C, lycopene, flavonoids, and other essential nutrients that can benefit humans significantly (Bhatt et al., 2001). The main goal of tomato breeding is to create cultivars with high yield, early maturation, attractive fruit shape, size, color, and resistance to different diseases (Choudhary et al., 1965). One of the safest methods to enhance goals is genetic improvement of quality characteristics, which appears to be the most suitable choice (Dawa et al., 2007). The quality and yield of tomato fruits are critical factors in determining their market value, and thus, tomato breeders aim to develop high-quality and high-yielding tomato varieties. Therefore, tomato breeding involves identifying and crossing parents with desirable traits to generate offspring with improved traits (Kumar et al., 1995; Kadam et al., 20000).

Agricultural businesses across the globe have started selling tomato hybrids due to their superiority over open-pollinated cultivars in terms of earliness, yield, and quality (Kumar et al., 1995; Narasimhamurthy and Gowda, 2013; Kadam et al., 2000; Kaushik et al., 2011). The Line x Tester mating design proposed by Kempthorne in 1957 has been widely adopted to determine the effects of GCA and SCA variances. When determining how effectively different genotypes can be combined to produce potential and productive populations, knowing their combining ability status is essential (Chen et al., 2019; Shalaby et al., 1983). The concept of general (GCA) and specific combining ability (SCA) is crucial. In this research, we aim to identify better parents for quality and yield-attributing traits in tomatoes using line tester crosses so, two distinct categories of tomato

cultivars were employed as genetic materials (Nasrin et al., 2009). To enhance the fruit size and preserve the fruit setting ability, it is suggested to hybridize the first group, which is sensitive to heat and has large fruit, with the second group, which is tolerant to heat and has small fruit (Mondal et al., 2009). Thus, the mating strategy employed would render it infeasible to conduct crosses between materials originating within the same group. Combining ability analysis is a valuable technique to gain insights into the genetic potential of parents and their hybrids. It also helps to identify gene effects and develop an effective breeding strategy. Considering this, a study was conducted to identify the most suitable parental combination with high yield and quality (Hannan et al., 2007).

Material and methods

Experimental material

The experiment was conducted at the vegetable research institute, AARI, Faisalabad. The experimental material of this study was comprised of three lines viz. Pakit, 88512, and Titano were used as female parents. Three testers Lyp. No. 1, H-24, and Nagina were used as male parents. The red fruit color and less lycopene characterize the Pakit. 88512 shows less redness when it ripens and Titano with cylindrical fruit and good shelf life. These lines' good fruit size and better shelf life make them highly suitable for commercial breeding. The testers Lyp. No. 1, H-24, and Nagina were resistant to tomato yellow leaf curl virus and with intermediate shelf life. These testers were collected from the University of Agriculture, Faisalabad, and AARI. The nine hybrids with Line X tester (3 X 3) were grown in vegetable research institute tomato farms. The nursery was sown(rabi) in September, transplanted in October, and harvested in January (2019).

Traits Evaluation and Data Analysis

The parental genotypes and F1 generations were assessed utilizing a randomized complete block design (RCBD). The crop was cultivated according to the customary cultural practices of the region, and seedlings that were thirty days old were transplanted into the experimental plot, spaced 90 × 40 cm apart. All of the recommended practices from the University of Agriculture, Faisalabad, were employed to ensure the production of a healthy and productive crop. Data were recorded for Plant height(cm), No. of branches, No. of Fruits/clusters, Lycopene (mg/100 g), Total soluble sugar, Yield(g), Fruit Shelf life(days), Fruit firmness(lbs/cm^2), and Total soluble solids (TSS). TSS % was measured with a hand refractometer, Fruit firmness with a fruit penetrometer, and yield on grams by calculating their means as shown in Table 1. The techniques outlined by Panse and Sukhatme (1967) were followed to analyze variance. Kempthorne's (1957) recommended method was applied to combine ability analysis, utilizing the average values of all the examined traits. The plant material and its breeding value were assessed by analyzing the F1 hybrids with heterosis or combining ability data for all traits.

Table 1: Mean performances of parents and hybrids for their traits

	Plant height (cm)	No. of branches/ plant	Lycopene (mg/100g)	No. of fruits/cluster	Total soluble sugar (%)	Fruit firmness (lbs/cm^2)	Yield/plant (g)
Lines							
Pakit	104*	25*	0.2*	6	13	6.98	3245*
88512	112	16	0.54*	5	24*	8	2853
Titano	101	20	0.34*	4	16.5*	7.33	2111
Mean	105.66	20.33	0.36	5	17.83	7.43	2736.3
Testers							
Lyp. No. 1	93*	28*	0.78	5	26.5*	4.6*	2764
H-24	92	26*	0.85	4	21	3.89	3324*
Nagina	89*	19.5	0.79	6.5	29.3*	4.94	2098
Mean	91.33	24.5	0.80	5.1	25.6	4.47	2728.6
Hybrids							
Pakit X Lyp. No. 1	89*	28*	0.44	5	32.5*	3.5	3264*
Pakit X H-24	64.3	28.5	0.69*	4.24	30.4*	4.3	2645
Pakit X Nagina	69.5	30*	0.63	6	38*	5.3	2675*
88512 X Lyp. No. 1	89.1	26	0.45	5.5	33*	6.92*	3444*
88512 X H-24	78*	30	0.68	3.5	36.8*	5.34	3865*
88512 X Nagina	74	31*	0.98*	5	34.3*	4.9*	3675*

Titano X Lyp. No. 1	61	27.5*	0.39	4.5	33*	5.8	3332*
Titano X H-24	69*	28*	0.77*	5	39*	5.3*	2987
Titano X Nagina	78	21	0.89*	4	34*	6.5*	3250
Mean	74.65	27.77	0.65	4.78	34.5	5.31*	3237.4*

Results

Mean performances of parents and their hybrids for various traits

The mean performance of lines and testers indicated that there is no single genotype that is superior in all the traits which were studied as shown in

Table ***1*.** Regarding fruit firmness, the testers were outperformed by certain lines, namely Pakit, 88512, and Titano. Among these lines, 88512 demonstrated the longest shelf-life of 34 days, with Titano coming in second with 29 days, and Pakit following closely behind with 28 days. The nine hybrid varieties did not exhibit superiority across all investigated traits. Nonetheless, traits such as the number of fruits per cluster, lycopene levels, total soluble solids (TSS), and fruit firmness were superior in the '88512 × Nagina hybrid. On the other hand, the 'Pakit × Lyp. No. 1' hybrid showed superiority in plant height and the number of branches, while the '88512 × H-24 hybrid exhibited superiority in yield per plant.

ANOVA for Combining Ability

Significant differences in the general combining ability of the lines were observed for all traits as shown in

Table ***2***. While there was substantial variability among testers for all the traits, except a few fruits per cluster, the differences were noteworthy. Nonetheless, apart from the number of fruits per cluster, all other traits exhibited a significant variance due to the Line x Tester interaction, which indicates that non-additive gene action predominates the genetic regulation of these characters.

Table 2: Analysis of Variance for Combining ability in respect of quality and Yield attributing traits of parents and hybrids of tomato

SOV	DF	Mean sum of squares						
		Plant height (cm)	**No. of branches/ plant**	**Lycopene (mg/100g) (%)**	**No. of fruits/cluster**	**Total soluble sugar (%)**	**Fruit firmness (lbs/cm^2)**	**Yield/plant (g)**
Lines(L)	2	124. 33*	22.55*	0.29*	0.25*	0.54**	4.88**	65386.53*
Testers(T)	2	226.45**	7.56**	0.48**	0.12*	2.74*	0.77**	3158*
LXT	4	89.76*	20.63**	0.39**	0.06	0.54**	0.43*	16253.1**
Error	8	4.36	1.87	0.04	0.01	0.02	0.05	6292.65

Estimation of General combining ability of parents

Based on the assessment of GCA effects for both lines and testers, it was observed that no individual line or tester exhibited strong general combining ability across all the traits examined, as shown in table 3. The effectiveness of the '88512' line as a general combiner was notable, with considerable GCA effects observed in the desired direction for important traits such as lycopene, TSS, fruit firmness, and yield per plant. Regarding testers, significant GCA effects for lycopene, TSS, and yield per plant were observed in 'Nagina'.

Table 3: Estimates of general combining ability effects of lines and testers for plant growth, fruit quality, and yield attributing traits in tomatoes.

	Plant height (cm)	**No. of branches/plant**	**Lycopene (mg/100g)**	**No. of fruits/cluster**	**TSS (%)**	**Fruit firmness (lbs/cm^2)**	**Yield/plant (g)**
Lines							
Pakit	2.9	3.21 **	-0.5 **	0.35*	-0.16	-0.58 **	-456 **
88512	2.63	-0.21	0.31 **	0.04	0.34 **	1.12 **	467.43 **
Titano	-4.93 **	3.03 *	-0.21 **	0.23	-0.24 **	-0.34	61.3
CD (5%)	3.4	1.9	0.03	0.24	0.19	0.36	117
Testers							
Lyp. No. 1	6.33 **	0.54	-0.23**	-0.03	-0.39 **	-0.22	-39
H-24	-6.83 **	-1.23 *	-0.3**	-0.01	-0.41 **	0.07	-59
Nagina	0.7	1.3	0.12 **	0.24*	0.89 **	0.27	89

CD (5%)	3.4	1.9	0.03	0.24	0.19	0.36	117

Estimation of Specific combining ability of Hybrids

There was no instance where a single cross displayed superior SCA across all the analyzed traits. However, among the characters studied, the cross between '88512' and 'Nagina' demonstrated good SCA for five traits: plant height, number of branches, number of fruits per cluster, lycopene content, and TSS. On the other hand, the cross between '88512' and 'H-24' exhibited a significant SCA effect on fruit firmness and was the second-best performing cross.

Discussion

Over the past few years, there has been a growing enthusiasm to breed high-yielding crops with superior quality. A promising technique to achieve this objective involves integrating traditional methods with spatial profiling and introgression breeding. In the case of tomato breeding, the compositional approach is a preferred method to enhance the organoleptic properties, such as nutritional attributes (e.g., increasing the levels of lycopene and flavonoids), improving the shelf life, and enhancing the overall fruit quality (Ahsan et al., 2013; Ali et al., 2013; Ali et al., 2016).

Assessing the combining ability of different genotypes provides valuable insights into how well they can be paired with specific genotypes to produce potential and productive offspring. This is where the concepts of general and specific combining ability come into play, as they assist breeders in selecting suitable parents for hybridization, identifying promising genotypes from the segregating population, and understanding the gene action involved in inheriting specific traits. While none of the crosses demonstrated consistently high specific combining ability across all the traits examined, one cross in particular, namely '88512 × Nagina', showed promising specific combining ability for five specific traits, plant height, number of branches, number of fruits per cluster, lycopene content, and total soluble solids (TSS). As a general trend, traits exhibiting better performance were consistently linked with the highest number of crosses, indicating significant SCA effects (Ali et al., 2014ab; Farooq et al., 2011).

Conclusion

After conducting the breeding program, it was concluded that the quality and yield of tomato fruit could be improved by utilizing traits attributed to heterosis breeding. The hybrid offspring exhibited superior characteristics such as increased fruit firmness, better fruit-keeping quality, higher yield components, and lycopene levels compared to the parent. It is noteworthy that the exploitation of hybrid vigor through heterosis breeding is the most viable technique for enhancing yield potential.

Declaration

Conflict of interest

The researchers affirm that there were no financial or commercial ties that might be seen as a potential conflict of interest throughout the research's execution.

Data Availability statement

All data generated or analyzed during the study have been included in the manuscript.

Ethics approval and consent to participate

These aspects are not applicable in this research.

Consent for publication

Not applicable

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