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ASSESSMENT OF MORPHOLOGICAL TRAITS IN TOMATO HYBRIDS FOR IMPROVED CULTIVATION PRACTICES

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***Abstract*:** *Tomato is widely used as a vegetable and plays an important role in the diet for its health benefits. The present research was carried out at the vegetable section of Barani Agricultural Research Institute (BARI), Chakwal, Pakistan, during the summer season of 2022. The experimental material used for the present study comprised 8 genotypes of tomato. Plant material was collected from the vegetable section of the plant breeding and genetics department in BARI Chakwal. Indeterminate genotype used for morphological characterization was LITH-904, LITH-908, LITH-942, LITH-949, LITH-970, SANDEL-F1, SAHEL-F1, and ANNA-F1. These genotypes were analyzed based on different morphological parameters. The observations recorded were subjected to different statistical analyses, and significant variations were observed among all the genotypes. The advantages of hybrid tomato cultivars are uniformity in shape and size, increased vigor, early maturity, high-yield, and resistance to specific pests and pathogens. The growth characteristics varied significantly among different tomato hybrids. The present research was conducted to evaluate different indeterminate tomato hybrids through various qualitative and quantitative traits to boost the future breeding programs of tomatoes to develop new high-yielding varieties. High yield and good processing qualities are the pre-requisites for the general acceptance of the hybrid by the farmers and the end consumer.*

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Introduction

Tomato (*Solanum lycopersicum* L.) is considered one of the most important crops and the second most used crop after potato (Siddiqui et al., 2020). It is a self-pollinating annual crop and belongs to the Solanaceae family with a chromosome number of 2n = 2x = 24 (Peralta et al., 2008). It is generally accepted that the tomato originated in the New World (America) from the Andes region, which now includes parts of Bolivia, Chile, Colombia, Ecuador, and Peru (Blanca et al., 2012). All of the evidence from different cultures of the tomato plant indicates that the tomato was first cultivated in Mexico. The main tomato producers are China, India, Turkey, and the United States. Total global tomato production in 2019 was 37.2 million tons (FAO STAT, 2021). Tomato is widely used as a vegetable and plays an important role in the diet for its health benefits (Salehi et al., 2019). Tomato nutritional content varies with tomato variety, extraction, control, and environment. During the processing of tomato products, up to 30% of their original weight becomes waste, which may still contain some beneficial nutrients (Paulino et al., 2020).

Along with its seeds and skin, it is the main waste product of tomatoes and is rich in protein, fiber, bioactive compounds, and lycopene (Lu et al., 2019). The product is a food supplement, especially in the meat industry (Domínguez et al., 2020). Tomatoes are versatile vegetables. Ripe tomatoes are eaten fresh and used to make many products such as tomato pastes, powders, ketchup, sauces, soups, and canned whole fruits; unripe green fruits are used in pickles, preserves, and eaten after cooking. It is an important source of lycopene, a phytochemical that protects cells from cancer-related oxidative damage (Salim et al., 2020). Despite its health benefits, tomatoes can have some adverse effects on the body when consumed in large quantities or poor condition. Eating tomatoes has side effects associated with kidney problems, allergies, arthritis, heartburn, and migraines (Salehi et al., 2019). Characterization is identifying and preserving those traits that are highly heritable,

distinct to the naked eye, and manifested in all contexts. It is necessary to gather all available germplasm for this crop before beginning any improvement programs, and their characterization is crucial for varietal development and selection. Because they provide an accessible means to measure genetic divergence, morphological and phenotypic characterizations have been utilised to assess genetic diversity (El-Aziz et al., 2016). Historically, the evaluation of tomato phenotypes has been centred on the traits of the seeds and fruits (El-Aziz et al., 2016; El-Mansy et al., 2015). Furthermore, plant identification, categorization, and taxonomy have all benefited from applying karyological investigations. These have significantly increased our understanding of plant genesis, evolution, and interactions (Wang et al., 2020).

Materials and methods

Experimental site

The field experiment was conducted at the vegetable section of Barani Agricultural Research Institute (BARI), Chakwal, Pakistan. It is situated at 32.90^{O}N latitude and 72.80^{O}E longitudes at an altitude of 498m. It has a semi-arid and sub-tropical climate characterized by extremely hot summer and cool winter. The soil is sandy loam in texture with a slight salinity. The climate is a subtropical region with dry weather with an average annual rainfall of 250-300 mm, mostly during monsoons. The average yearly temperature is 27^{O}C.

Plant material

The plant material used for the recent study comprises 8 genotypes of tomato germplasm. Plant material was collected from the breeding department of the vegetable section at BARI Chakwal. The genotypes that were selected are given below:

Genotype name	
LITH-904	LITH-970
LITH-908	SANDEL-F1
LITH-942	SAHEL-F1
LITH-949	ANNA-F1

Nursery cultivation

Seeds of tomato hybrids were sown in plastic plug trays on Jan 15, 2022 using soil media with a composition of Soil : FYM : Sand (1:1:1) respectively. These plastic trays were placed inside the nursery tunnels to get healthy and disease-free seedlings. The seedlings were ready for transplanting after 45 days of sowing. The seedlings were transplanted on March 07, 2022 on well-prepared raised beds at 4.5 x 1.50 m on both sides spacing. The plant-to-plant distance was maintained at 40 cm, and the row-to-row distance was kept at 75 cm. Regular irrigation, hoeing, fertilization, stacking, and crop protection measures were adopted as per crop demand.

Transplanting

Before transplantation of tomato, well rotten FYM was mixed in the soil and ploughed in it. Land was completely prepared for tomato plants. The rotavator and disc plough was used for ploughing purposes. Water availability was stopped two days before transplanting to make it easy. On the day of transplanting provide maximum water to uproot the plants. Seedling roots were dipped in copper oxychloride - a fungicide, with a concentration of 2g per liter, was used to protect plants from root rot.

Cultural practices

Fruit borer is very common pest in tomatoes. Fruit borer attack was seen in the tunnel, so Emamectin spray at the rate of 5g/L was given against the fruit borer in the tunnel. The sprays were presented during the reproductive stage of the crop when fruit borer appears to be severe causing economic damage. The observations of fruit borer larvae were recorded from different plants. Spraying was done by using an air-compressing knapsack sprayer. The whitefly is an important phloem-feeding pest of worldwide agriculture that damages host plants by secreting toxic saliva, removing phloem sap, and transmitting viruses. Imidacloprid spray was used against the attack of aphids and white flies. Fruit fly is also a very common pest in tomatoes. Fruit flies damage tomato fruit by laying eggs under the skin. The larvae that hatch from these eggs feed on the decaying flesh. Infested fruit becomes rotten and inedible, causing considerable loss in production. Trichlorofon with a concentration of 7g/L was used to overcome the attack of fruit flies.

Boron application

Boron has a good effect on the production and quality of tomatoes. Crop plants need boron for the uptake of calcium and the transport of carbohydrates. As it helps in the development of fruit and also avoids fruit from cracking. Boron application reduces fruit disorders and makes the cell wall more strengthen. Excess boron is toxic to plants, so care must be taken to ensure correct application rate and even coverage. While boron may be sprayed on leaves, excess will cause plant damage. 5g/L Boron was applied in the tomato tunnel as it helps develop fruit and prevents fruit from cracking.

Data collection

Data were collected randomly from three plants in each row of the tunnel. The following parameters were measured i.e. number of flowers, fruit/inflorescence, number of inflorescences, fruit length, fruit width, fruit firmness, total soluble solvent, pericarp thickness, and yield.

Statistical analysis

Data were analyzed using MS Excel 2019 and Statistix 8.1. Tables and path analysis were measured using Excel 2019 while correlation, regression, and analysis of variance were calculated using Statistix 8.1. The difference between means was studied by

least significant difference (LSD) at 5% probability (Steel et al., 1997).

Results and discussion

Different results have been identified during the experiment. Table 1 shows that plants with more inflorescence have more fruit and flower rate, which ultimately increases fruit yield and production. The maximum inflorescences was observed in SAHEL-F1 (8.33), followed by SANDEL-F1 (6.33). The result showed that a maximum number of flowers/inflorescences was produced in LITH-949 (13), followed by SANDEL-F1 (4.67). Studies show that entries that developed more flower/inflorescence yielded more fruit. This character is directly linked with yield. The maximum number of fruit/clusters was produced in LITH-949 (9.33), followed by SANDEL-F1 (7.33) fruits/clusters were observed. It was observed that the number of fruits per cluster is the most important component trait directly related to increased fruit yield. Maximum number of inflorescences is observed in SAHEL-F1 (7.67), followed by SANDEL-F1 in which number of inflorescences is (6.33). Results show that a greater number of the inflorescence have more fruit and flower rate and thus more yield and higher production. The result showed that the maximum fruit length was produced in LITH-904 (7.7 cm), followed by SANDEL-F1, which was (7.67 cm). Fruit length is also a varietal character. More fruit length has maximum nutrient contents, and a maximum number of seeds will be stored in it. The result showed that maximum fruit width was produced in LITH-904 (5.9 cm), followed by SANDEL-F1 in which fruit was (5.13). Study showed that variation in fruit width is associated with genetic makeup and governed by cell size and intercellular space of the flesh (Ahmad et al., 2012; Ali et al., 2013,2014ab, 2016; Hafee et al., 2021; Javed et al., 2012; Puspito et al., 2015). Fruit width is a varietal development character. More fruit width has many nutrient contents beneficial for health purposes. The result shows maximum fruit firmness was observed in SANDEL-F1 (0.63) followed by LITH-970 (0.8). Fruit firmness is a qualitative trait; if it is higher, it is good, cooking, and easily digestible. While lower fruit firmness is good against harder pests and contains higher water content. The result showed that maximum TSS were produced in LITH-904 in which (6.05 $Brix^0$) followed by SANDEL-F1 in which (5.12 $Brix^0$) was observed. The total content of soluble solids on fruits (TSS) is a key trait as it influences final product flavour and consistency and ultimately determines the final yield after processing. The total content of soluble solids is a key character as it affects final product flavour and consistency, ultimately determining the final yield after processing. It is also the most important quality parameter for nutrition and quality. The result showed that maximum pericarp thickness was produced in LITH-904 (0.95 cm) followed by LITH-908 in which pericarp thickness was (0.83 cm). From the results, it was observed that entries which developed minimum pericarp thickness would be the top preference of consumers. The high pericarp thickness is due to the pericarp cells, which contain more starch grains, and the accumulation of assimilates is also more. The result showed that maximum yield produced in LITH-908 was (33.8 kg) followed by LITH-970 in which the yield was (32.6 kg). Previous results showed that fruit/cluster was also maximum than average. Fruit width and size fruit size were also good in LITH-908. Yield is a varietal character, and mainly depends upon different parameters like flower cluster, fruit cluster, fruit length and pericarp thickness (Aaliya et al., 2016; Abbas et al., 2015, 2016; Zafar et al., 2022).

Table 1: Mean differences between different genotypes according to the measured parameters

	NF	F/I	NI	FL	FW	FF	TSS	PT	Yield/plant
G1	6.67 ± 0.33	5.67 ± 0.33	6 ± 1	7.7 ± 0.12	5.9 ± 0.12	1.37 ± 0.09	6.05 ± 0.03	0.95 ± 0.01	30.6 ± 0.15
G2	9 ± 2	5 ± 1.15	6 ± 0.58	5.6 ± 0.15	4.37 ± 0.09	0.97 ± 0.15	4.03 ± 0.08	0.83 ± 0.01	33.8 ± 0.17
G3	10 ± 1.53	6.67 ± 1.86	6 ± 0.58	6.17 ± 0.12	4.4 ± 0.27	1.2 ± 0.15	4.07 ± 0.12	0.73 ± 0.01	31.4 ± 0.20
G4	13 ± 2.65	9.33 ± 2.33	7 ± 0	6.8 ± 0.1	4.47 ± 0.08	1.73 ± 0.12	4.53 ± 0.12	0.60 ± 0.01	29.3 ± 0.21
G5	4.33 ± 0.67	8.67 ± 2.73	7 ± 0.58	7.57 ± 0.18	5.03 ± 0.09	0.8 ± 0.1	5.04 ± 0.09	0.71 ± 0.01	33.6 ± 0.11
G6	4.67 ± 0.33	7.33 ± 1.33	6.33 ± 0.33	7.67 ± 0.09	5.13 ± 0.09	0.63 ± 0.07	5.12 ± 0.04	0.54 ± 0.01	24.3 ± 0.17
G7	4.67 ± 0.33	5.67 ± 0.67	7.67 ± 0.33	7.03 ± 0.15	4.7 ± 0.06	1.13 ± 0.09	4.02 ± 0.44	0.69 ± 0.01	22.5 ± 0.05
G8	4.67 ± 0.67	3.67 ± 0.88	6.33 ± 0.88	6.83 ± 0.12	4.23 ± 0.12	1.63 ± 0.09	3.43 ± 0.12	0.62 ± 0.01	25.6 ± 0.26

G1=LITH-904, G2=LITH-908, G3=LITH-942, G4=LITH-949, G5=LITH-970, G6=SANDEL-F1, G7=SAHEL-F1, G8=ANNA-F1; NF= no of flowers, F/I= fruit /inflorescence, NI= no of inflorescence, FL= fruit length, FW= fruit width, FF= fruit firmness, TSS= total soluble solvent, PT= pericarp thickness

Correlation analysis

As we know that the correlation analysis is used to find the significance differences between two traits. The table indicated that the correlation between characteristics was highly significant and some were non-significant. According to table 2, fruit width have highly significant difference with TSS (0.888) and with fruit length (0.662) and non-significant negative correlation with fruit firmness (-0.259). As yield is the main focusing objective in any breeding program, the yield significantly correlates with plant thickness (0.549). There is a negative correlation between yield

and number of inflorescence (-0.249) and fruit firmness (-0.075).

Table 2: Correlation analysis for comparison

Traits	NF	F/I	NI	FL	FW	FF	TSS	PT
F/I	0.431*	1						
NI	-0.186	0.090	1					
FL	0.425*	0.182	0.239	1				
FW	-0.293	0.001**	0.077	0.739**	1			
FF	0.335	-0.125	0.083*	-0.161	-0.207	1		
TSS	-0.034	0.259*	-0.109	0.662**	0.888**	-0.259	1	
PT	0.040	-0.208	-0.178	-0.138	0.438*	0.062	0.380*	1
Y/P	0.355*	0.160**	-0.249	-0.337	0.045*	-0.075	0.222*	0.549**

**=highly significant, *=significant, ns=non-significant, NF=Number of flowers, F/I=fruit/inflorescence, NI=number of inflorescence, FL=fruit length, FW=fruit width, FF=fruit firmness, TSS=total soluble solid, Y/P= yield per plant

Path coefficient analysis

Path analysis measures different parameters' direct and indirect effects on our main focusing trait, i.e., yield. According to table 3, pericarp thickness has the highest positive direct effect on the yield of tomatoes. If breeders focus on the pericarp thickness, it would be possible to increase the production of tomato varieties. While fruit length, fruit width, and fruit firmness negatively affect yield.

Table 3: Path coefficient analysis for direct and indirect effects

Traits	NF	F/I	NI	FL	FW	FF	TSS	PT	*Yield*
NF	0.032	0.013	0.042	-0.002	0.552	-0.257	-0.797	2.721	2.305
F/I	0.002	0.149	0.055	-0.152	-0.368	0.108	-0.682	-4.241	-5.128
NI	0.005	0.035	0.233	-1.44	0.713	-0.655	-0.529	-5.726	-7.36
FL	4.275	0.011	0.172	-1.953	0.918	-0.880	1.689	0.772	0.722
FW	-0.00	0.012	-0.037	0.406	-4.416	0.256	0.237	-1.282	-4.828
FF	0.008	-0.016	0.154	-1.736	1.145	-0.990	1.458	3.784	3.808
TSS	-0.006	-0.026	-0.032	-0.857	-0.274	-0.377	3.828	9.338	11.592
PT	0.005	-0.037	-0.078	-0.088	0.333	-0.220	2.104	16.984	19.003

NF=Number of flowers, F/I=fruit/inflorescence, NI=number of inflorescences, FL=fruit length, FW=fruit width, FF=fruit firmness, TSS=total soluble solid

Conclusion

The present research entitled "Assessment of Morphological Traits in Tomato Hybrids for Improved Cultivation Practices" was carried out at the vegetable section of Barani Agricultural Research Institute (BARI), Chakwal, Pakistan, during the summer season of 2022. The experimental material used for the present study comprised 8 genotypes of tomato. The advantages of hybrid tomato cultivars are uniformity in shape and size, increased vigor, early maturity, high yield, and resistance to specific pests and pathogens. The growth characteristics varied significantly among different tomato hybrids. The results showed that genotypes LITH-908 and LITH-970 were the highest-yielding varieties among all eight genotypes. The present research was conducted to evaluate different indeterminate tomato hybrids through various qualitative and quantitative traits to boost the future breeding programs of tomatoes to develop new high-yielding varieties.

Conflict of interest

The authors declared the absence of conflict of interest.

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