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Research Article

Marjan F_1: A Semi-Determinate Tomato Hybrid Exhibiting High Yield Potential and Improved Resistance to Diseases

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ABSTRACT

The development of locally adapted, disease-tolerant and high-yielding semi-determinate tomato hybrids is an emerging focus in agricultural research of Pakistan. These hybrids are designed to address challenges such as disease resistance, particularly against fungal and viral infections, while ensuring high productivity coupled with suitable fruit traits and adaptability to environmental conditions. In Punjab, determinate, indeterminate and semi-determinate tomatoes are cultivated, however, their production is heavily reliant on plant protection measures, making cultivation both costly and largely confined to farmers' fields. Marjan F_1, a semi-determinate tomato hybrid was developed with a fair degree of tolerance against fungal diseases, making it well-suited for open-field cultivation. Its resistance enables cultivation with reduced dependence on plant protection inputs. Additionally, Marjan F_1 is highly suitable for kitchen gardening, as it can be cultivated with minimal plant protection measures, thereby allowing home gardeners to grow it organically. In yield trials, Marjan F_1 demonstrated a 3.98% yield advantage over three exotic check hybrids (TO-1057 F_1, T-1359 F_1 and TO-6242 F_1). It showed resistance to late blight, gray mold and Fusarium wilt, while maintaining moderate resistance to early blight. Overall, Marjan F_1 exhibited superior disease resistance compared to two exotic checks (TO-1057 F_1 and TO-6242 F_1), coupled with better yield performance.

Keywords: Fruit yield, Hybrid, Marjan F_1, Disease Resistant, Semi-determinate, Tomato

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INTRODUCTION

The tomato (*Solanum lycopersicum* L.) possessing a chromosome number of 2n=2x=24 (Gatahi, 2020) is the second widely cultivated vegetable crop after the potato in the World. Its edible fruit is botanically classified as a berry but commonly used as a vegetable in culinary contexts. It is native to Andean region of South America including Peru, Ecuador and Bolivia (Yadav *et al*., 2013). Tomato belongs to the *Solanaceae* family (nightshade family), which also includes potato, eggplant and peppers. Tomatoes are a staple ingredient in cuisines worldwide, renowned for their rich flavor and versatility. Although tomatoes do not rank high in terms of caloric value, however, by virtue of the volume consumed in various forms such as cooked, salad, soup, preserves, pickles, ketchup, sauces, it is considered a high value crop (Soytong *et al*., 2021). Additionally, sun-dried tomato and tomato powder production trend is also increasing in world. Tomatoes are also valued for their nutritional benefits, being rich in vitamins A and C, potassium, and antioxidants like lycopene, which has been linked to various health benefits (Saeed *et al*., 2014; Raza *et al*., 2022). It has commercial value in the extraction of tomatine, a steroidal hormone, which is used as a substitute of diosgenin (Mishra *et al*., 2020). Its increasing consumption makes it a high value crop for generating income to the farmers.

The global production of tomato is about 192 million tons with notable annual growth rate of 1.5% over the last decade. China (70.21 million tons) and India (20.42 million tons) are the leaders in global tomato production (FAOSTAT, 2023). In Pakistan, tomato is grown on an area of 0.06 million ha, producing 0.762 million tons, with an average yield of 11.07 t/ha. Presently, Pakistan's total annual consumption of tomato is 1.06 million tonnes. Of the total requirement 0.762 million tonnes (70%) are met through local production while 0.356 million tonnes (30 %) are fulfilled through import. Pakistan imported tomato fruit of worth 56.67 million US $ while exports are amounted to and 8.00 million US $ (FAOSTAT, 2023). This huge import is burden on economy of Pakistan, therefore it is needed to increase local production on unit area basis.

Tomatoes are grown in a wide range of climates, from temperate to tropical regions. The optimal temperature for the growth and flowering of the tomato crop is 21 – 24 °C, which supports both summer and winter cultivation (Iftikhar *et al*., 2021). Tomato is a rapidly growing crop with a growing period of 90 to 180 days. It is a day neutral plant and larger differences between day and night temperatures, however, adversely affect yield. As tomato is a mild season crop, it is difficult to grow and get its production round the year at one location in Pakistan under natural conditions due to extreme temperatures (Chishti *et al*., 2019). Temperatures above 25 °C, when accompanied by high humidity and strong wind, result in reduced yield. Night temperatures above 20 °C accompanied by high humidity and low sunshine lead to excessive vegetative growth and poor fruit production. High humidity leads to a greater incidence of pests and diseases and fruit rotting, therefore, dry climates are preferred for tomato production (Iftikhar *et al*., 2021).

During tomato cultivation a lot of attention has to be paid in preventing and combating different biotic and abiotic stresses, which can significantly affect tomato production (Sharma *et al*., 2019 and Javed *et al*., 2022). These biotic stresses severely affect plant health, fruit quality and overall yield. Lack of resistant varieties and poor disease management practices worsen the problem. The major cause of low productivity of tomato crop in Pakistan is disease infestation such as early blight, bacterial and fusarium wilt and tomato yellow leaf curl virus along with poor availability of seed of local hybrids (Solangi *et al*., 2022; Fatima, *et al.,* 2024).

The presence of fungal diseases has made many growers rely heavily on fungicide application and some fungicides such as fenhexamid and pyraclostrobin and boscalid formulas have been reported to be effective against these kinds of diseases (Domínguez *et al*., 2012). Considering the present situation, there is a need to develop tomato hybrids and open pollinated varieties possessing suitable characters with fair degree of tolerance against diseases. Late blight, gray mold and Fusarium wilt severely affect tomato crops leading to a significant reduction in productivity (Panno *et al.,* 2021). Tomato breeding objectives in Pakistan should incorporate genetic advancements in yield improvement and pest resistance, utilizing indigenous germplasm to develop superior local tomato varieties possessing high yield and disease resistance traits (Malik, *et al.,* 2018; Ong *et al*., 2020).

To prevent disease incidence, pesticides are applied, however, their residues often remain in tomato fruits and repeated applications may accumulate to toxic levels, making them less desirable for table consumption. Moreover, frequent sprays significantly increase the overall cost of production. Pakistan has imported 49.22 tons tomato seed of worth 7.27 million US dollars during the year 2023-24 (Pakistan Bureau of Statistics, Karachi, Pakistan, 2023-24). Particularly, semi-determinate hybrids contribute a major share in imported tomato seed, therefore, seed production of locally developed tomato hybrid will lead in reduction of tomato seed import in Pakistan (Ali, *et al.,* 2020; Saleem, *et al.* 2016). Furthermore, development of local tomato hybrid and their commercial seed production will lead to development of local seed industry and increase in employment opportunities in Pakistan. The present study describes the development of a high yielding and disease tolerant tomato hybrid for kitchen gardening with less plant protection requirement

MATERIALS AND METHODS

Breeding Background/Developmental History

In tomato, hybrid breeding programme at Vegetable Research Institute (VRI), Faisalabad was initiated during the year 2001-02. By the end of a 2005-06, a sufficient number of determinate purelines has been developed and hybridization efforts to produce new local hybrids were initiated in the same year. Till the year 2013-14, 332 experimental hybrids were synthesized and evaluated subsequently for general cultivation. In this regard, semi determinate hybrid Marjan F_1 (LTH-324) was developed during 2013-14. It was evaluated in a preliminary yield trial conducted at VRI, Faisalabad during 2014-15. Due to its encouraging yield performance, it was tested in station yield trial during 2015-16. Based on its performance in preliminary and station yield trials, multi-locational/zonal yield evaluations were conducted from 2016-22 (over 6 years) at five different locations (Vegetable Research Institute, Faisalabad; Vegetable Research Sub-

Station, Sheikhupura; Vegetable Research Sub-Station, Raiwind; Vegetable Research Sub-Station, Multan & Vegetable Research Sub-Station, Bahawalpur). This hybrid proved better than imported hybrid (TO-1057 F_1) in terms of earlier fruit setting, fruit ripening ability and single fruit weight (Table 1). In terms of fruit yield and especially disease resistance, Marjan F_1 performed better than two exotic check hybrids TO-1057 F_1 and TO-6242 F_1 (Table 2 & 3). In recognition of its superior overall performance and desirable morphological traits, the hybrid was approved during the 56th meeting of Punjab Seed Council held on 24th March 2023.

Data Collection

Following studies were made for data collection.

Morphological Studies

The data on valuable morphological parameters were measured by using vernier caliper, measuring scale and through visual observations, whereas; in case of fruit firmness 10 randomly selected fruits were examined with the help of penetrometer (kg/cm^2) and the average was computed. Single fruit weight of randomly selected 10 fruits was measured by using a digital weighing balance (g) and the average was calculated (Nadeem *et al*., 2024).

Fruit Yield (T/ha)

The data on three morphological traits (Fruit firmness, fruit weight and fruit yield) were taken. Fruit yield data was recorded on net plot basis by using a digital weighing balance (g) and yield (Ton/ha) was computed as per usual procedure.

Pathological Studies

Pathological studies were conducted at Plant Pathology Section, Plant Pathology Research Institute, Ayub Agricultural Research Institute, Faisalabad, during two consecutive years (2020-21 and 2021-22). Fungal diseases (early blight, late blight, gray mold and Fusarium wilt) were recorded in tomato trials by using different disease rating scales (Pandey *et al*., 2003; Gondal *et al*., 2012; Kumar *et al*., 2018).

Entomological Studies

Entomological studies were carried out at Entomological Research Institute, Faisalabad during two consecutive years (2020-21 and 2021-22). Fruit borer infestation was measured by dividing the number of infested fruits with the total number of fruits and aphid population is estimated by observing aphid/leaf in field (visual in situ counting method).

Nutritional Studies

The nutritional composition of four key tomato fruit constituents viz: lycopene, beta-carotene, vitamin C and total sugar was determined by an authorized Testing Lab using the official method of analysis (AOAC, 2016).

DNA Fingerprinting Studies

DNA finger printing was done using testing method of PCR-SSRs by the Agricultural Biotechnology Research institute, AARI, Faisalabad. Samples leaves of Marjan F1 hybrid and commercial hybrids (Salar F1, Saandal F1 and Sundar F1) were collected from tomato fields of Vegetable Research Institute and stored at 4°C only for few hours before DNA extraction. DNA was extracted using a method developed by Tanksley's group (Cornell University, Ithaca, N.Y.), with some minor modifications. Then amplification is done by PCR and DNA finger printing was completed using different molecular markers given in the Supplementary File 1.

Statistical Analysis

Data significance was estimated by using second-order statistics. Analysis of all quantitative traits was carried out by using analysis of variance (Steel and Torrie, 1980) with the MSTATC (Ver. 1.5, Michigan State University, East Lansing, Michigan, USA).

RESULTS AND DISCUSSION

Salient Traits of Marjan F_1

The botanical characterization revealed that Marjan F_1, a semi-determinate hybrid, exhibited earlier 50% flowering and fruit setting along with higher single fruit weight and higher fruit yield potential as compared to TO-1057 F_1 (Table 1; Figure 1).

Evaluation of Marjan F_1 in yield trials

The tomato hybrid Marjan F_1 which was coded as LTH-324 (after its synthesis) was tested in replicated Varietal Yield Trials for consecutive eight years (Table 2). It was evaluated in terms of yield against three exotic check entries T-1359 F_1, TO-1057 F_1 and TO-6242 F_1. It produced slightly lower fruit yield (34.07 T/ha) in comparison with check entry T-1359 F_1 (34.61 T/ha) during four year trials (2014-18) (Yadav *et al*., 2013 and Gautum *et al*., 2018). On account of seed unavailability of T-1359 F_1 and prevalence of TO-1057 F_1 in the market, during next two years (2018-20) it was evaluated against TO-1057 F_1.

Table 1. Botanical description of Marjan F_1 compared with TO-1057 F_1.

No.	Botanical features	Marjan F_1	TO-1057 F_1
Adult plant			
1	Growth habit	Spreading	Spreading
2	Growth type	Semi-determinate	Semi-determinate
3	Average plant height (cm)	120	110
4	Average stem thickness (mm)	15.4	12.9
5	Stem hairiness	Medium	Medium
6	Stem anthocyanin	Weak	Weak
7	Leaf color	Green	Green
8	Leaf length (cm)	12.7	12.5
9	Leaf width (cm)	5.6	5.4
Flower			
10	Days to 50% flowering	49	53
11	Flower color	Yellow	Yellow
12	Flower size	Medium	Medium
13	Calyx color	Green	Green
14	Anther color	Yellow	Yellow
Fruit			
15	Days to 50% fruit setting	133	140
16	Fruit color	Red	Red
17	Fruit shape	Round	Oblong
18	Fruit size	Medium	Medium to small
19	Fruit length (cm)	4.7	5.5
20	Fruit width (cm)	4.9	4.7
21	Fruit shape index (L/W)	0.95	1.17
22	Fruit ribs	Weak	Weak
23	Fruit top	Round	Semi-round
24	Fruit firmness (kg/cm^2)	3.81	3.85
25	Average fruits/cluster	7	6
26	Average single fruit weight (g)	82.4	74.5
27	Potential fruit yield (T/ha)	53.63	52.12
Seed			
28	Seed color	Light brown	Light brown
29	Seed shape	Semi-round compressed	Semi-round compressed
30	Seed length (mm)	3.38	3.37
31	Seed width (mm)	2.64	2.63
32	Seed thickness	0.75	0.75
33	1000-seed weight (g)	3.19	3.17

Marjan F_1 produced higher fruit yield (33.34 t/ha) in comparison with TO-1057 F_1 (24.59 t/ha) with 35.0 % increase in fruit yield (Saleem *et al*., 2013). In next two years (2020-22), Marjan F_1 was tested against two exotic check hybrids namely TO-1057 F_1 and TO-6242 F_1.

It produced higher fruit yield (43.53 t/ha) in comparison with TO-1057 F_1 (39.35 T/ha) and TO-6242 F_1 (42.99 T/ha) with 5.96% increase in fruit yield over average of both checks. Based on the mean performance across all experiments, Marjan F_1 recorded a fruit yield of 36.75 T/ha surpassing the combined average yield of the three checks (35.34 T/ha), thereby exhibiting a 3.98% increase in fruit yield (Chishti *et al*., 2008; Mishra *et al*., 2020 and Quamruzzaman *et al*., 2023). In fruiting pattern, the Figure 1 shows that at the end of May, Marjan F1 tolerate heat stress and disease resistance still plants are green and check is affected and green plants become brownish and fruiting is less green. Marjan F1 shows more fruiting in green form. The minutes of meeting of Variety Evulation Committee of Punjab Seed Corporation (PSC) for approval of Marjan F_1 hybrid are given in Supplementary File 2.

Figure 1. Plant stand and fruiting pattern of Marjan F_1 (LTH-324) (A) and TO-1057 F_1 (B).

Pathological Studies

The results in Table 3 revealed that Marjan F_1 has better resistance against late blight, gray mold and Fusarium wilt and remained at par against early blight in comparison with the two exotic check hybrids namely TO-1057 F_1 and TO-6242 F_1. It appears that Marjan F_1 performed better in terms of diseases resistance and hence it produced higher fruit yield (3.98%) compared to two exotic check hybrids. Similar yield advantages associated with disease resistance have been previously reported by Saleem *et al*. (2015; 2016). Kumar *et al*. (2018) also reported fungal diseases like late blight, early blight and Fusarium wilt are major diseases and cause fruit yield reduction in tomato. Given its resistance profile, Marjan F_1 can be cultivated with fewer fungicide sprays at the commercial scale, lowering production costs. In addition, its suitability for organic cultivation makes it an appealing choice for kitchen gardening and for consumers seeking healthier alternatives.

Entomological studies

The entomological observations conducted at the Entomological Research Institute, AARI, Faisalabad, during 2020-21 and 2021-22 revealed that Marjan F_1 (LTH-324) exhibited negligible pest infestation, showing only 9.67% fruit borer incidence and an average of 4.26 aphids per leaf, both lower than the check hybrid TO-1057 F_1 (11.02% and 5.27, respectively) (Table 4). These findings indicated that Marjan F_1 possesses comparative tolerance to key insect pests under Faisalabad's agro-ecological conditions. Similar results have been reported by Kamboh *et al*. (2025) who identified *Helicoverpa armigera* as the predominant fruit borer species in tomato fields across Pakistan, noting that certain hybrids exhibit natural resistance due to morphological and biochemical traits. Dhanda (2023) further highlighted that pest pressure in tomato fluctuates with seasonal and environmental factors, reinforcing the importance of hybrid selection for field resilience. Studies by Singh *et al*. (2021) also confirmed that fruit borer infestation intensifies during the flowering and fruiting stages, consistent with the period of light incidence observed on Marjan F_1 in the current study. Regarding aphid populations, Akhter *et al.* (2023) and Tomar *et al*. (2024) reported significant genotypic variability among tomato cultivars, where hybrids with compact canopy structures and dense trichomes showed reduced aphid colonization. These contemporary findings collectively support the present study's results, indicating that Marjan F_1 (LTH-324) possesses inherent tolerance against fruit borer and aphid attack, making it a promising and stable hybrid for sustainable tomato cultivation under local conditions.

Table 2. Yield Comparison of Marjan F_1 with three exotic Checks

S. No.	Year	Name of Trial	No. of Entries	Location	Fruit yield (t/ha)				% increase/ decrease over check		LSD (0.05)
					Marjan F_1 (LTH-324)	T-1359 F_1	TO-1057 F_1	TO-6242 F_1			
1	2014-15	Preliminary	22	Faisalabad	20.41	19.20	-	-	6.3		2.38
2	2015-16	Station	9	Faisalabad	30.53	20.43	-	-	49.4		1.95
3	2016-17	Multi-location	12	Faisalabad	47.52	48.41	-	-	1.8 (-)		4.64
4			12	Sheikhupura	40.88	46.55	-	-	13.9 (-)		2.57
5			12	Multan	33.87	42.59	-	-	25.7 (-)		3.07
6			12	Bahawalpur	22.17	31.58	-	-	42.4 (-)		2.29
7	2017-18	Multi-location	10	Faisalabad	48.30	48.04	-	-	0.5		3.72
8			10	Sheikhupura	39.75	37.96	-	-	4.7		2.41
9			10	Multan	35.20	32.15	-	-	9.5		2.15
10			10	Bahawalpur	22.08	19.14	-	-	15.4		2.03
Average of 4 years (2014-18)					34.07	34.61	-	-	1.56 (-)		-
11	2018-19	Multi-location	10	Faisalabad	35.19	-	24.18	-	45.5		3.40
12			10	Sheikhupura	33.03	-	22.33	-	47.9		2.16
13			7	Raiwind	27.13	-	21.58	-	25.7		2.33
14			10	Bahawalpur	25.23	-	20.73	-	21.7		2.29
15	2019-20	Multi-location	10	Faisalabad	45.70	-	31.57	-	44.8		3.35
16			10	Sheikhupura	37.19	-	27.96	-	33.0		1.97
17			7	Raiwind	31.09	-	24.55	-	26.6		2.03
18			10	Bahawalpur	32.18	-	23.84	-	35.0		2.38
Average of 2 years (2018-2020)					33.34	-	24.59	-	35.0		-
19	2020-21	Multi-location	12	Faisalabad	50.30	-	44.14	48.12	13.9	4.53	2.87
20			12	Sheikhupura	45.96	-	39.31	44.91	16.9	2.33	2.84
21			12	Raiwind	43.52	-	36.09	41.81	20.6	4.08	2.21
22			12	Bahawalpur	38.84	-	33.46	38.7	16.1	0.36	2.40
23	2021-22	Multi-location	10	Faisalabad	53.63	-	52.12	52.43	2.9	2.28	3.61
24			10	Sheikhupura	41.25	-	37.92	40.64	8.8	1.50	2.74
25			10	Raiwind	39.80	-	37.94	39.41	4.9	0.98	2.23
26			10	Bahawalpur	34.95	-	33.87	37.94	3.2	-7.88	2.07
Average of 2 years (2020-22)					43.53	-	39.35	42.99	10.9	1.02	-
Combined Average (All 26 experiments)					36.75	35.34			3.98 (+)		-

Nutritional analysis

The estimation of nutritional parameters in tomato fruit, including lycopene, vitamin C, total sugars and beta-carotene was carried out following the standard analytical procedures prescribed by the Association of Official Analytical Chemists (AOAC, 2016). At the Pakistan Council of Scientific and Industrial Research (PCSIR), Lahore, samples from both hybrids (Marjan F_1 and the check TO-1057 F_1) were analyzed under uniform laboratory conditions using AOAC-approved protocols: lycopene and β-carotene were quantified spectrophotometrically according to AOAC 970.64, vitamin C was determined by 2,6-dichlorophenol-indophenol titration (AOAC 967.21) and total sugars were estimated following the Lane-Eynon titrimetric method (AOAC 923.09).

Table 3. Disease incidence on Marjan F_1 (LTH-324) recorded by the Plant Pathology Section, Ayub Agricultural Research Institute, Faisalabad.

No.	Year	Disease	Marjan F_1 (LTH-324)	TO-1057 F_1	TO-6242 F_1
1	2020-21	Late blight	Resistant	Moderately Resistant	Moderately Resistant
		Early blight	Moderately Resistant	Moderately Resistant	Moderately Resistant
		Gray mold	Resistant	Moderately Susceptible	Resistant
		Fusarium wilt	Resistant	Moderately Resistant	Moderately Resistant
2	2021-22	Late blight	Resistant	Resistant	Moderately Resistant
		Early blight	Moderately Resistant	Moderately Resistant	Moderately Resistant
		Gray mold	Resistant	Moderately Susceptible	Moderately Resistant
		Fusarium wilt	Resistant	Moderately Resistant	Moderately Resistant

Table 4. Pests infestation data on Marjan F_1 (LTH-324) recorded by the Entomological Research Institute, AARI, Faisalabad, during 2020-21 to 2021-22 (Average of two years).

Entries	Fruit borer (% infestation)	Aphid (Population per leaf)
Marjan F_1 (LTH-324)	9.67	4.26
TO-1057 F_1	11.02	5.27

Table 5. Nutritional analysis of tomato fruit conducted by the Pakistan Council of Science & Industrial Research (PCSIR), Ferozpur Road, Lahore, during 2019-20 to 2020-21 (Average of two years).

Hybrids	Lycopene (mg/100 g)	Vitamin C (mg/100 g)	Total Sugar (%)	Beta Carotene (mg/100 g)
Marjan F_1	4.01	59.84	4.70	0.37
TO-1057 F_1	2.45	53.58	4.05	0.25

The application of these standardized AOAC methods provided reliable and comparable data across years (2019-20 and 2020-21), confirming the nutritional superiority of Marjan F_1, which recorded higher concentrations of all four biochemical constituents compared with the check hybrid. The results showed that the average of all the four nutritional components lycopene (4.01 mg/100g), Vitamin C (59.84 mg/100g), Total sugar (4.70 %) and Beta carotene (0.37 mg/100g) are higher in Marjan F_1 than check entry TO-1057 F_1 having lycopene (2.45 mg/100g), Vitamin C (53.58 mg/100g), Total sugar (4.05 %) and Beta carotene (0.25 mg/100g). Therefore, on account of better nutritional traits, it is highly recommended for daily table and cooking purposes.

DNA Fingerprinting

Molecular characterization through DNA fingerprinting is a reliable approach for assessing genetic distinctiveness and relatedness among crop hybrids. In the present study, Marjan F_1 was evaluated using PCR-based Simple Sequence Repeat (SSR) markers and a Cultivar Identification Diagram (CID) was constructed through UPGMA cluster analysis to visualize genetic relationships among commercial tomato hybrids (Figure 3). The dendrogram revealed a wide range of genetic similarity coefficients (0.44–0.96) suggesting substantial polymorphism and genetic diversity among the studied genotypes. The phylogenetic tree (Cultivar Identification Diagram) based on PCR-SSR markers illustrated the genetic relationships among commercial tomato hybrids, showing the position of Marjan F_1 relative to Salar F_1, Saandal F_1 and Sundar F_1 (Figure 3). Closely clustered cultivars share shorter branch lengths, indicating a higher degree of genetic similarity and possible common ancestry, while longer branches represent greater genetic divergence. In this analysis, Marjan F_1's placement within the tree reflects its distinct genetic identity while still showing partial relatedness to other hybrids, suggesting shared allelic patterns derived from related breeding lines.

The SSR-based clustering thus confirms Marjan F_1 as a genetically distinguishable hybrid within the evaluated set, supporting its authenticity and aiding in cultivar identification and protection. The clustering pattern demonstrated that Marjan F_1 occupied an independent branch, distinctly separated from the commercially available hybrids Salar F_1, Saandal F_1 and Sundar F_1 showing genetic dissimilarities of 42%, 41% and 41% respectively. Although Samar F_1 is 96% similar to Marjan F_1 due to one of its same parental line (Figure 3), but both hybrids belong to different segments. Marjan F_1 is semi-determinate segment hybrid and Samar F_1 is indeterminate segment hybrid, therefore they are two different hybrids.

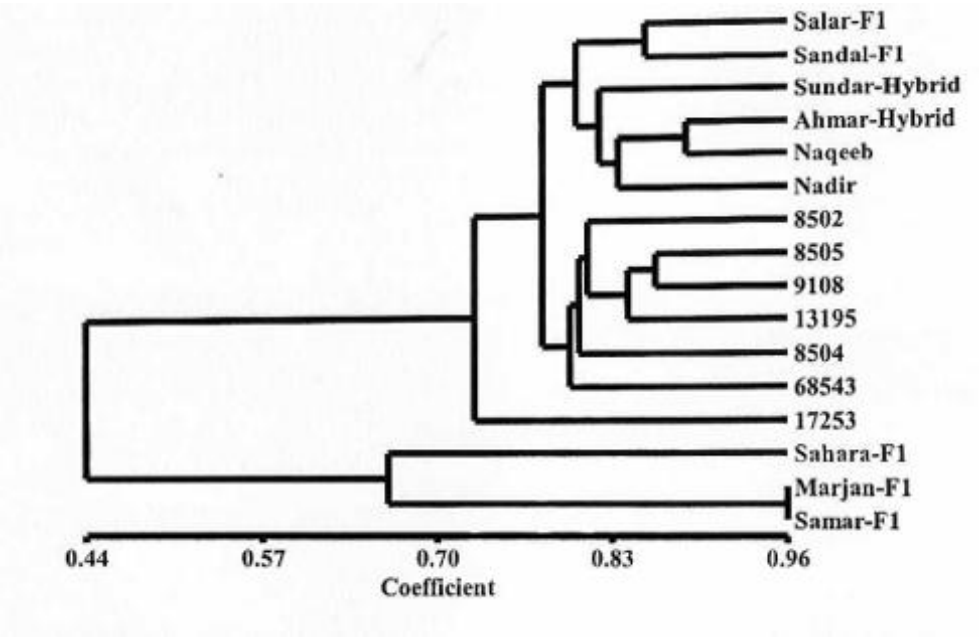

Figure 3. Cultivar Identification Diagram developed by Agricultural Biotechnology Research Institute, AARI, Faisalabad.

CONCLUSION

The study concludes that the newly developed hybrid Marjan F_1 demonstrated superior performance. Its resistance against major fungal diseases allows cultivation with reduced plant protection measures, thereby lowering production costs while ensuring better fruit quality with minimal pesticide residues. Furthermore, its adaptability makes it particularly suitable for organic farming and kitchen gardening, where spray applications are often impractical.

AUTHOR CONTRIBUTIONS

Muhammad Iqbal helped in planning of hybrid development trials. Kashif Nadeem and Mudassar Iqbal conducted the trials of Marjan F_1 hybrid as main breeders. Ghazanfar Hammad conducted the statistical analysis of these trials. Sadia Sardar and Ayesha Sardar conceptualized and drafted the manuscript. Maria Anjum helped in scientific write-up. Atif Ali and Ghazanfar Hammad contributed to editing and refining of manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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REFERENCES

Akhter, W., Hassan, M. U., & Ahmad, A. (2023). Botanical biopesticides and their influence on tomato quality through pest control in developing countries. Journal of Integrative Agriculture, 22(5), 1234–1242.

Ali, S., Khan J., Jadoon A., Riaz M. and Khan, A. (2020). Evaluation of farmers socioeconomic characteristics influencing tomato output in district Peshawar, Khyber Pakhtunkhwa, Pakistan. Sarhad Journal of Agriculture, 36(3), 894-899.

AOAC (2016). Official methods of analysis of AOAC International, 20th edition. Published by AOAC International, Suite 300, 2275 Research Blvd., Rockville, Maryland 20850 – 3250 USA.

Chishti S. A. S., Hussain, M. M., Ali, I., Nadeem, K., Saeed, A. and Jalil, S. (2019). Temperature based crop modeling for round the year tomato production in Pakistan. Journal of Agricultural Research 57(1), 25-32.

Chishti, S. A. S., Khan A. A., Sadia, B. and Khan, I. A. (2008). Analysis of combining ability for yield, yield components and quality characters in tomato *(Lycopersicon esculentum* MILL.) Journal of Agricultural Research, 46(4), 325-332.

Dhanda, S. (2023). A review on seasonal succession and management of key insect pests infesting tomato. Horticultural Science (Prague), 50(1), 1–10.

Domínguez, I., Ferreres, F., Riquelme, F. P. D., Font, R., Gil, M. I. (2012). Influence of preharvest application of fungicides on the postharvest quality of tomato (*Solanum lycopersicum* L.). Postharvest Biology and Technology, 2, 1-10.

FAOSTAT, (2023). Food and Agriculture Organization (FAO).

Fatima, A., Ali, S., Azmat, S., Amrao, L., Ghani, M. U., Iftikhar, Y., Zeshan, M. A., Ahmad, A. and Kalsoom, H. (2024). Morphological Assessment of Resistance Potential in Tomato against Early Blight Disease and Its Management. Pakistan Journal of Agricultural Research, 37(2), 176-184.

Gatahi, D. M. (2020). Challenges and Opportunities in Tomato Production Chain and Sustainable Standards. International Journal of Horticultural Science and Technology, 7(3), 235-262.

Gautam, N., Kumar M., Vikram A., Kumar S. and Sharma S. (2018). Heterosis Studies for Yield and its Components in Tomato (*Solanum lycopersicum* L.) under North Western Himalayan Region, India. International Journal of Current Microbiology and Applied Sciences, 7(2), 1949-1957.

Gondal A. S, Ijaz, M., Riaz, K. and Khan, A. R. (2012). Effect of different doses of fungicide (Mancozeb) against Alternaria leaf blight of tomato in tunnel. Journal of Plant Pathology & Microbiology, 3(3), 1-3. doi:10.4172/2157-7471.1000125.

Iftikhar, Y., Mubeen, M., Sajid, A., Zeshan, M.A., Shakeel, Q., Abbas, A., Bashir, S., Kamran, M. and Anwaar, H. (2021). Effects of Tomato Leaf Curl Virus on Growth and Yield Parameters of Tomato Crop. Arab Journal of Plant Protection, 39(1), 79-83.

Javed, A., Nawab N. N., Gohar S., Akram A., Javed K., Sarwar M., Tabassum M.I., Ahmad N. and Mallhi A. R. (2022). Genetic Analysis and Heterotic studies in tomato (*Solanum Lycopersicum* L.) hybrids for fruit yield and its related traits. SABRAO Journal of Breeding and Genetics, 54(3), 492-501.

Kamboh, G. S., Chandio, A. H. and Soomro, S. A. (2025). Assessment of colored light and pheromone traps for fruit borer in tomato in Pakistan. Pakistan Journal of Agricultural Research, 24(1), 11560.

Kumar, S. P., Srinivasulu, A. and Babu, K. R. (2018). Symptomology of major fungal diseases on tomato and its management. Journal of Pharmacognosy and Phytochemistry, 7(6), 1817-1821.

Malik, A. M., Mughal, K. M., Mian, S. A. and Khan, A.U. (2018). Hydroponic tomato production and productivity improvement in Pakistan. Pakistan Journal of Agricultural Research, 31(2), 133-144.

Mishra A., Nandi, A., Sahu, G. S., DAS, S., Mohanty, I. C., Pattanayak, S. K. and Tripathy, P. (2020). Studies of combining ability in tomato (*Solanum lycopersicum* L.) for vegetative growth, yield and quality traits. Journal of Pharmacognosy and Phytochemistry, 9(1), 466-473.

Ong, S. N., Taheri, S., Othman, R. Y. and Teo, C. H. (2020). Viral disease of tomato crops (*Solanum lycopesicum* L.): an overview. Journal of Plant Diseases and Protection, 127(10), 725–739.

Pakistan Bureau of Statistics, Karachi, Pakistan. (2023-24).

Pandey, K. K., Pandey, P. K., Kalloo, G. and Banerjee, M. K. (2003). Resistance to early blight of tomato with respect to various parameters of disease epidemics. Journal of General Plant Pathology, 69(6), 364-371.

Panno, S., Davino, S., Caruso, A. G., Bertacca, S., Crnogorac, A., Mandi´c, A., Noris, E. and Mati´c, S. (2021). A Review of the Most Common and Economically Important Diseases That Undermine the Cultivation of Tomato Crop in the Mediterranean Basin. Agronomy, 11(11), 2188-2232.

Quamruzzaman, A., Akter, L. and Islam, F. (2023). Yield and Pest Performance of High-Temperature Tolerant Tomato (*Lycopersicum esculentum*) Lines for Year-Round tomato production in Bangladesh. Agricultural Sciences, 14, 855-863.

Raza B., Hameed A and Saleem MY (2022). Fruit nutritional composition, antioxidant and biochemical profiling of diverse tomato (*Solanum lycopersicum* L.) genetic resource. Frontiers in Plant Science, 13, 1035163. doi: 10.3389/fpls.2022.1035163.

Saeed A., Hassan, N., Shakeel, A., Saleem, M. F., Khan, N. H., Ziaf K., Khan, R. A. M. and Saeed N.. (2014). Genetic analysis to find suitable parents for development of tomato hybrids. Life Science Journal, 11(12s), 30-35.

Saleem, M. Y., Akhtar, K. P., Iqbal, Q., Asghar, M., Hameed A. and Shoaib M. (2016). Development of tomato hybrids with multiple disease tolerance. Pakistan Journal of Agricultural Sciences, 48(2), 771-778.

Saleem, M. Y., Akhtar, K. P., Iqbal, Q., Asghar, M., Hameed, A. and Shoaib M. (2015). Development of high yielding and blight resistant hybrids of tomato. Pakistan Journal of Agricultural Sciences, 52(2), 293-299.

Saleem, M. Y., Qumer I. and Muhammad A. (2013). Genetic variability, heritability, character association and path analysis in F1 hybrids of tomato. Pakistan Journal of Agricultural Sciences, 50(4), 649-653.

Sharma, P., Thakur S. and Negi R. (2019). Recent Advances in Breeding of Tomato- A Review. International Journal of Current Microbiology and Applied Sciences, 8(3), 1275-1283.

Singh, A. D., Kumar, V., & Sharma, P. (2021). Seasonal incidence of major insect pests of tomato during Rabi season. International Journal of Current Microbiology and Applied Sciences, 10(6), 53–63.

Solangi, S.A., Hajano, J.U.D., Syed, R.N., Otho, S.A., Wagan, K.H., Ahmed, A.M., Khoso, F.N., Jarwar, A.R. and Qazi, S.T. (2022). Screening of tomato varieties for resistance to tomato leaf curl viral disease under field conditions. Pakistan Journal of Agricultural Research, 35(1), 70-77.

Soytong, M., Guevarra, P. R., Mateo, J. M. C. and Galvez, H. F. (2021). Evaluation of tomatoes fruits flesh colour, beta-carotene and lycopene content. International Journal of Agricultural Technology, 17(2), 727-736.

Steel R.G.D. and Torrie, J. H. (1980). Principles and Procedures of Statistics, a Biometrical Approach. 2nd edition. McGraw Hill Book Company, New York.

Tomar, N., Singh, P., Sasode, R. S., Bhadauria, N. S. and Singh, U. C. (2024). Screening of tomato varieties/hybrids against aphid (Aphis gossypii Glover) under field condition. Journal of Advances in Biology & Biotechnology, 27(9), 1–10.

Yadav, S. K., Singh, B. K., Baranwal, D. K. and Solankey S. S. (2013). Genetic study of heterosis for yield and quality components in tomato (*Solanum lycopersicum*). African Journal of Agricultural Research, 8(44), 5585-5591.