Original Article

Effect of Pollination Timing on Tomato Hybrid Seed Traits of Cross-Pollinated Common and Cherry Tomatoes

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Abstract The study was conducted during the 2023/24 growing season at the Horticulture Department of the Ministry of Agriculture. It involved crossbreeding three local tomato parents and four cherry tomato mothers using the Line x Tester method. The seeds were sown on 14/12/2023 and then transplanted into the plastic house on 20/1/2024. The parents were arranged in a factorial experiment using a RCBD to conduct the pollination process which was carried out on three different dates: 15/3, 15/4, and 1/5. The seeds from the hybrids for each pollination date were collected separately for testing. The results showed that the second pollination date outperformed in all the studied traits. The P2 X S2 hybrid excelled in fruit number, fruit set percentage, and germination percentage at 10.58 fruits per flower, 53.28%, and 99.11%, respectively. The P2 X S4 hybrid significantly outperformed in terms of seed number, producing 18.97 seeds. The interaction had a significant effect, as the T2- P2 X S2 treatment excelled in number of set fruits, fruit set percentage, and germination percentage, yielding 15.00 fruits, 75%, and 99.69%, respectively. The T2-P1 X S2 treatment outperformed in the number of seeds at 30.33 while T2-P3 X S4 excelled in seed weight and germination vigor at 3.31 g and 25.67%, respectively.

Keywords: Pollination timing, Tomato hybrids, Seed quality, Germination vigor.

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Introduction

The tomato (*Solanum lycopersicum*) belongs to the Solanaceae family while the cherry tomato (*Solanum lycopersicum* var. cerasiforme) is an important vegetable crop worldwide due to its nutritional and commercial value, adaptability to various agricultural environments, and good productivity (7). The cherry tomato is among the several crops that have not received adequate attention despite their economic importance and high nutritional value. Therefore, research on them should be expanded, for the benefit of producers and consumers. Cherry tomatoes were not known locally but have recently been introduced to domestic markets, where they have gained much popularity among consumers due to their diverse shapes, sizes, colors, and unique taste, and are now widely used in modern cuisine (4).

The importance of the tomato as a strategic crop with continuous demand in the markets throughout the year has garnered considerable attention from plant breeders to produce new high-yielding hybrids and cultivars which can tolerate the prevailing conditions of the country (9). These new varieties possess excellent quality, capable of competing with

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imported products available in the market and rivaling the performance of imported hybrid seeds. The tomato plant grows and flowers at optimal temperatures of between 18 °C at night and 24 °C during the day. While it can tolerate low temperatures, it stops growing and flowering at 10 °C, and can withstand high temperatures of up to 35 °C (3).

One of the top priorities for plant breeders is to determine the optimal time to conduct hybridization in order to save time and effort, as well as to achieve the highest number of set flowers. However, this aspect has been neglected by researchers, and there are no studies or recommendations regarding it under the country's climatic conditions (2). In commercial hybridization processes, the biggest challenge for producers is the significant loss of flowers, which leads to seed loss. Moreover, determining the best timing can reduce the working hours of pollination staff, thus lowering production and labor costs (8 and 14).

Given the above, this study aimed to identify the best time for hybridization and the best hybrids for yielding the highest seed output and the best quality traits.

Materials and Methods

The seeds of the common tomato parents and cherry tomato mothers (Table 1) were sown in polystyrene trays inside the greenhouse of the National Program for the Propagation of Local Vegetable Hybrids and Lines on 14/12/2023. The seedlings were then transplanted after full growth on 20/1/2024 into the plastic house prepared for planting. They were planted in three replicates using a randomized complete block design (RCBD) for the pollination process using the Line x Tester method, with 20 flowers per cross. Each pollinated flower was marked with the corresponding pollination date according to the following timings: T1 on 15/3, T2 on 15/4, and T3 on 1/5. This arrangement aimed to obtain 12 hybrids of the F1 generation, with each hybrid containing seeds from three different pollination dates, resulting in 36 seed sources. These were replicated thrice, creating a factorial design with factors 3×3×12, totaling 108 experimental units.

Table 1. Vegetative growth and fruit characteristics of the genotypes in the study.

Symbol	Line Name	Specifications	Origin
♂			
P1	S25	Large, lobed, juicy, red fruits	Min. of Agriculture
P2	1006	Large, red, spherical, tapered-end fruits with high TSS and dense growth	Min. of Agriculture
P3	1015	Large, red fruits	Min. of Agriculture
♀			
S1	LA-3002	Cherry, spherical, small, red fruits	United States
S2	IND-0712	Cherry, spherical, orange fruits	United States
S3	KH-1003	Cherry, spherical, red fruits	National Program
S4	CHM-1	Cherry, red, elongated, abundant, small fruits	National Program

Studied Traits:

1. Average number of set fruits (fruit per flower): The set fruits were manually counted in each experimental unit, and the average was calculated (1).
2. Fruit set percentage (%): Calculated by determining the ratio of the number of set flowers to the total number of flowers (20 flowers) using the formula:
   Fruit Set % = (No. of Set Flowers/Total No. of Flowers) × 100 …. (2).
3. Number of seeds per fruit (seed per fruit): The number of seeds in the ripe fruits was counted after extraction, as specified in ISTA (3).
4. Average seed weight (gram per seed): Measured using a precision scale (1).
5. Germination vigor (%): Calculated by determining the percentage of

germinated seeds after seven days of planting in polystyrene trays using a peat moss medium (3 and 13).

Germination percentage (%): Based on the formula:

Germination % = (No of Germinated Plants/No of Seeds Planted) × 100 (12).

Results and Discussion

Number of set fruits (fruit per flower): The results in Table 2 indicate significant differences between pollination timings and hybrids. The T2 treatment outperformed the others, providing the highest average number of set fruits at 12.24 fruits while the lowest value was 7.76 fruits for T3. The P2 X S2 hybrid excelled significantly producing 10.66 fruits compared to the lowest for P3 X S3 at 8.44 fruits. The interaction effect was also significant, with the T2-P2 X S2 treatment giving the highest value of 15.00 fruits, while the lowest was observed in T1-P2 X S1 at 11.00 fruits.

Table 2. The effect of pollination timing on the number of set fruits in the common and cherry tomato hybrids.

P X S	T			Mean
	T1	T2	T3	P X S
P1 X S1	10.67	11.33	8.17	10.04
P1 X S2	8.93	14.00	8.33	10.42
P1 X S3	8.63	12.93	8.60	10.06
P1 X S4	7.00	12.23	7.00	8.74
P2 X S1	8.00	11.00	7.07	8.69
P2 X S2	9.33	15.00	7.63	10.66
P2 X S3	6.80	11.87	8.10	8.92
P2 X S4	8.80	12.00	8.07	9.62
P3 X S1	7.74	11.33	6.87	8.56
P3 X S2	8.73	14.33	8.67	10.58
P3 X S3	7.00	11.00	7.31	8.44
P3 X S4	8.00	11.04	7.34	8.78
Mean T	**8.28**	**12.34**	**7.76**	
LSD 0.05	T 0.587	P X S	1.147	T – PXS 2.033

Fruit set percentage: Table 3 shows the significant differences between treatments. The T2 pollination timing produced the highest fruit set percentage, reaching 61.68%, while the lowest was for the T3 at 38.82%. The P2 X S2 hybrid outperformed the others, achieving the highest rate of 53.28%, whereas the lowest percentage was observed in P3 X S3. The interaction effect was also significant, with the T2-P2 X S2 treatment achieving the highest fruit set percentage of 75.00% compared to the lowest at 34.00% for the T1-P2 X S3.

Table 3. The effect of pollination timing on the fruit set percentage of the common and cherry tomato hybrids.

P X S	T			Mean
	T1	T2	T3	P X S
P1 X S1	53.33	56.67	40.83	50.28
P1 X S2	44.67	70.00	41.67	52.11
P1 X S3	43.17	64.67	43.00	50.27
P1 X S4	35.00	61.17	35.00	43.72
P2 X S1	40.00	55.00	35.33	43.44
P2 X S2	46.67	75.00	38.17	53.28
P2 X S3	34.00	59.33	40.50	44.61
P2 X S4	44.00	60.00	40.33	48.11
P3 X S1	37.33	56.67	34.33	42.78
P3 X S2	43.67	71.67	43.33	52.89
P3 X S3	35.00	55.00	36.67	42.22
P3 X S4	40.00	55.10	36.76	43.89

Mean T	**41.40**	**61.68**	**38.82**	
LSD 0.05	T 2.93	P X S 5.87	T – PXS	10.16

Number of seeds per fruit (seed per fruit): The data in Table 4 show significant differences between pollination timings, hybrids, and their interactions on the number of seeds per fruit. The T2 pollination timing outperformed the others, giving the highest number of seeds at 24.83, while T1 gave the lowest at 19.50. The P1 X S2 hybrid produced the highest number of seeds 26.52 whereas the P2 X S4 hybrid produced the lowest number at 18.97 seeds. For the interaction, a significant effect on this trait was produced by the T2-P1 X S2 treatment at 30.33 seeds, while T1-P3 X S3 gave the lowest number of seeds 16.67.

Table 4. The effect of pollination timing on the number of seeds per fruit (seed per fruit) of the common and cherry tomato hybrids.

P X S	T			Mean
	T1	T2	T3	P X S
P1 X S1	20.40	24.30	22.53	22.41
P1 X S2	22.83	30.33	26.40	26.52
P1 X S3	20.70	22.13	20.13	20.99
P1 X S4	17.67	22.00	18.67	19.44
P2 X S1	17.33	21.00	19.00	19.11
P2 X S2	20.67	31.00	21.33	24.33
P2 X S3	18.47	24.67	19.17	20.77
P2 X S4	16.97	20.90	19.03	18.97
P3 X S1	20.67	25.67	18.33	21.56
P3 X S2	23.33	29.00	21.33	24.56
P3 X S3	16.67	24.00	20.37	20.34
P3 X S4	18.33	23.00	19.67	20.33
Mean T	19.50	24.83	20.50	
LSD 0.05	T 0.67	P X S 1.34	T – PXS	2.32

Seed weight (g): The results in Table 5 indicate significant differences between pollination timings, hybrids, and their interactions in seed weight. The T2 treatment showed the best results, with a seed weight of 2.34 g, while the lowest value was observed in treatment T1 at 1.78 g. The hybrids also varied in seed weight, with P3 X S4 giving the highest average at 2.56 g, while P1 X S3 produced the lowest at 1.63 g. The interaction had a significant effect on the weight of 1,000 seeds, with the T2-P3 X S4 treatment giving the highest weight of 3.31 g, and the T1-P1 X S1 the lowest at 1.55 g.

Table 5. The effect of pollination timing on seed weight (g) of the common and cherry tomato hybrids.

P X S	T			Mean
	T1	T2	T3	P X S
P1 X S1	1.55	1.96	1.70	1.74
P1 X S2	1.91	2.77	2.18	2.29
P1 X S3	1.50	1.79	1.60	1.63
P1 X S4	1.73	2.15	1.88	1.92
P2 X S1	1.57	1.94	1.72	1.75
P2 X S2	1.95	2.75	2.11	2.27
P2 X S3	1.53	1.93	1.84	1.77
P2 X S4	1.79	2.18	2.08	2.02
P3 X S1	1.58	1.94	1.81	1.78
P3 X S2	2.06	2.98	2.05	2.36
P3 X S3	1.98	2.38	2.37	2.24
P3 X S4	2.17	3.31	2.17	2.56
Mean T	**1.78**	**2.34**	**1.96**	
LSD 0.05	T 0.075	P X S 1.50	T - PXS	0.260

Germination vigor (%): Table 6 shows the significant differences between treatments, with T2 outperforming the others in terms of germination vigor at 18.40% and T1 the lowest at 12.08%. The P3 X S4 hybrid significantly excelled, showing the highest germination vigor at 17.36%, compared to the lowest at 10.62% for P3 X S3. The interaction effect was also significant with the T2-P3 X S4 treatment showing the best result at 25.67%, while the lowest vigor was recorded in T1-P3 X S3 at 8.66%.

Table 6. The effect of pollination timing on the germination vigor (%) of the common and cherry tomato hybrids.

P X S	T			Mean P X S
	T1	T2	T3	
P1 X S1	10.00	15.66	11.50	12.39
P1 X S2	16.00	20.90	13.00	16.63
P1 X S3	9.00	13.00	10.33	10.78
P1 X S4	**12.10**	**24.00**	**12.67**	**16.27**
P2 X S1	10.13	15.90	10.67	12.23
P2 X S2	14.66	19.66	14.33	16.22
P2 X S3	9.33	12.33	10.83	10.83
P2 X S4	13.67	24.66	13.66	17.33
P3 X S1	10.76	14.46	11.66	12.30
P3 X S2	16.33	23.00	12.00	17.11
P3 X S3	8.66	11.53	11.67	10.62
P3 X S4	13.43	25.67	13.00	17.36
Mean T	**12.08**	**18.40**	**12.11**	
LSD 0.05	T 0.426	P X S 0.853	T – PXS	1/478

Germination percentage: The data in Table 7 reveal highly significant differences in germination percentage. The T2 pollination timing outperformed the others, with its seeds achieving the highest germination rate of 98.06%, while the lowest value was 96.42% in T1. The P2 X S4 hybrid gave the highest germination rate of 99.11%, while the lowest was recorded in the P2 X S3 at 95.11%. As for the interaction effect, the T2-P2 X S2 treatment achieved the highest germination rate of 99.69%, while T1-P2 X S3 gave the lowest at 92.67%.

Table 7. The effect of pollination timing on the germination percentage of the common and cherry tomato hybrids.

P X S	T			Mean P X S
	T1	T2	T3	
P1 X S1	97.67	97.67	96.00	97.11
P1 X S2	97.33	98.67	97.00	97.67
P1 X S3	97.33	98.00	97.33	97.56
P1 X S4	99.00	99.67	98.67	99.11
P2 X S1	97.00	97.33	96.33	96.89
P2 X S2	97.33	99.69	97.00	98.00
P2 X S3	92.67	96.00	96.67	95.11
P2 X S4	97.33	98.33	96.67	97.44
P3 X S1	96.00	97.00	93.33	95.44
P3 X S2	96.00	98.67	97.33	97.33
P3 X S3	95.00	97.67	95.67	96.11
P3 X S4	95.33	98.00	95.00	96.11
Mean T	**96.50**	**98.06**	**96.42**	
LSD 0.05	T 0.498	P X S 0996	T – PXS	1.726

As seen in Tables 2, 3, and 4, different pollination timings produced significant variations in fruit set percentages, number of seeds per fruit, and average seed weights among the hybrids. The variation in fruit set percentages can be attributed to the negative effects of low temperatures and high relative humidity during the pollination and fertilization period, which may lead to functional male sterility and hinder the dispersal of pollen grains, even though they remain viable. This results in the failure to form seeds in the fruits, producing hollow, seedless fruits (10) (Appendix 1).

Additionally, Tables 5, 6, and 7 clearly show that flowers setting under favorable weather conditions yield seeds with a good weight, which positively reflects on germination vigor and overall germination percentage. They also show a decline in seed weight, germination percentage, and germination vigor in the third hybridization timing, possibly due to the negative effects of high temperatures and low relative humidity. These conditions may cause elongation of the styles, leading to a self-incompatibility system of the pin type, as well as style desiccation, negatively affecting fruit set percentage. This results in the production of fewer and shriveled seeds and accelerates fruit ripening, depleting the fruit's nutrient reserves and shortening the seed filling period.

The availability of ideal environmental conditions for pollination and fertilization positively impacted both the quantity and quality of the produced seeds. This was clearly evident from the results in Tables 5, 6, and 7, where favorable conditions caused a significant increase in seed vigor, germination percentage, and seed weight, which were most pronounced in the second timing of Or April 15 the outperforming the results of the other two timings. These findings are consistent with (4 and 9).

Appendix 1. Meteorological data on maximum and minimum temperatures and humidity over the different pollination dates (1).

TIME STAMP	Air Temperature (^{0} C)			Rel Humidity (%)		Avg Wind Speed (kilometers/hr)
	Max	Min	Avg	Max	Min	
2024-03-15	28.21	9.79	20.83	60.84	15.46	0.45
2024-03-16	28.10	15.09	22.15	63.8	26.56	3.859
2024-03-17	26.07	12.64	19.31	66.43	20.98	0.281
2024-03-18	26.78	11.22	19.68	64.59	18.49	5.215
2024-03-19	23.40	16.94	19.98	87	25.05	3.823
2024-03-20	22.75	13.73	17.33	87.3	53.55	2.42
2024-04-10	35.15	23.23	29.19	55.05	26.17	2.078
2024-04-11	31.05	16.76	23.91	79.16	20.9	0.711
2024-04-12	29.04	15.12	22.08	75.48	24.55	0.53
2024-04-13	29.75	14.85	22.30	77.83	22.6	1.379
2024-04-14	31.41	15.87	23.64	69.1	12.56	1.798
2024-04-15	33.34	16.15	24.75	63.37	12.35	0.96
2024-05-01	29.99	18.74	24.37	89.9	29.97	1.191
2024-05-02	29.25	18.48	23.87	90.8	41.99	8.76
2024-05-03	30.04	19.45	24.75	85.5	41.9	2.686
2024-05-04	29.76	19.58	24.67	87.4	36.39	5.306
2024-05-05	32.00	31.91	31.96	86.1	23.89	9.17
2024-05-06	30.21	18.00	24.10	78.92	24.18	3.379

Conclusion

The findings of this study show April 15th as the best time for hybridization as it achieved the highest seed production with superior quality traits, such as the highest fruit set percentage, 1000-seed weight, and germination percentage and vigor. Also, the P2 X S2 hybrid produced the highest seed weight, germination percentage, and germination vigor, making it one of the promising hybrids for future breeding and improvement programs. For the interaction treatment, the T2-P2 X S2 excelled, achieving the highest seed weight, germination percentage, and germination vigor.

As seen above, optimizing pollination timing under favorable environmental conditions significantly enhances both seed quantity and quality. Specifically, mid-season pollination (April 15th) resulted in better outcomes across multiple traits, suggesting that the environmental factors of temperature and humidity during this period are crucial for maximizing seed viability and vigor. Therefore, aligning hybridization schedules with these optimal conditions can be a key strategy for improving seed production efficiency and quality in breeding programs. This highlights the importance of fine-tuning agricultural practices to specific climate windows for better crop performance. The selection of genetic compositions involved in the production of F1- hybrids also plays an important role in increasing the production of hybrid seeds for commercial purposes.

Supplementary Materials

No Supplementary Materials.

Author Contributions

Author 1: methodology, writing—original draft preparation; both authors: writing—review and editing. Both authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

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Conflicts of Interest

The authors declare no conflict of interest.

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مقالة أصيلة

تأثير مواعيد التلقيح في صفات بذور هجن الطماطة الناتجة من التضريب بين الطماطة الاعتيادية والكرزية

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قسم البستنة وهندسة الحدائق، كلية الزراعة، جامعة الانبار، الانبار، العراق

الخلاصة

اجريت الدراسة للموسم الزراعي ٢٠٢٣/٢٠٢٤ في احد البيوت المحمية التابعة لدائرة البستنة –وزارة الزراعة، للتضريب بين ثلاثة اباء من الطماطة المحلية واربع امهات من الطماطة الكرزية بطريقة السلالة x. الفاحص، زرعت البذور بتاريخ ١٤/ ١٢ / ٢٠٢٣ ثم نقلت الى البيت البلاستيكي ٢٠/ ١ / ٢٠٢٤، وزعت الإباء والامهات في تجربة عامليه بتصميم القطاعات العشوائية الكاملة (R.C.B.D) لإجراء عملية التلقيح والتي كانت بثلاثة مواعيد هي ١٥/ ٣ و ١٠/ ٤ و ١/ ٥ ، ثم جمعت بذور الهجن للمواعيد المذكورة كلا على حده لإجراء الاختبارات عليها. اظهرت النتائج تفوق موعد التلقيح الثاني T2 15 / 4 في جميع الصفات المدروسة. تفوق الهجين P2 X S2 في صفات عدد الثمار ونسبة العقد% ونسبة الانبات اذ اعطى ١٠.٥٨ ثمرة زهرة⁻١ و٥٣.٢٨٪ و ٩٩.١١٪ بالتتابع، تفوق الهجين P2 X S4 معنويا في صفة عدد البذور واعطى ١٨.٩٧ بذرة والهجينP3 X S4 في صفتي وزن البذور وقوة الانبات وأعطى ٢.٦٥غم بذرة⁻١ و ١٧.٣٦٪ بالتتابع. كان للتداخل اثرا معنويا فقد تفوقت المعاملة T2- P2 X S2 في صفات عدد الثمار العاقدة ونسبة العقد% ونسبة الانبات% واعطت ١٥.٠٠ ثمرة و٧٥٪ و ٩٩.٦٩٪ بالتتابع والمعاملة T2- P1 X S2 في عدد البذور ٣٠.٣٣ بذرة والمعاملة T2- P3 X S4 في صفات وزن البذور غم بذرة⁻١ وقوة الانبات % واعطت، ٣.٣١ غم و٢٥.٦٧٪ بالتتابع.

كلمات مفتاحية: مواعيد التضريب، هجن الطماطة، نوعية البذور، قوة الانبات.

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