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Research Note

A comprehensive approach to improve brinjal hybrid seed yield through emasculation, timing, and crossing ratio

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Abstract
Brinjal hybrid seed production primarily utilizes the seed-to-seed method. Optimal results require synchronized stigma receptivity and pollen viability, timing of emasculation and pollination along with the appropriate quantity of pollen on the female parent's stigma. With this perspective, the research was carried out, employing the parents of the GJBH 4 brinjal hybrid. The study involved 18 experiments, considering two emasculation options namely emasculation on same day as flower opening, emasculation on a day prior to flower opening, three pollination times namely 8-9 am, 9-10 am and 10-11 am and three cross-pollination ratios namely two female flowers per male flower, four female flowers per male flower, six female flowers per male flower. The results revealed that for better hybrid seed yield, emasculation on the day prior to flower opening, pollination between 9-10 am and using one male flower to pollinate four female flowers could be adopted.

Keywords: Brinjal, Crossing ratio, Day of emasculation, Pollination, Viability

Eggplant (*Solanum melongena* L.), commonly referred to as brinjal or aubergine, holds significant agricultural importance within the Solanaceae family. It is prominently grown across South Asian countries, including Bangladesh, India, and Pakistan, where it occupies approximately half of the total cultivated land for this vegetable (Alam *et al*., 2003). India is recognized as the primary center of origin of this crop. It exhibits large variations collectively as cultivars and land races in various parts of the country (Anbarasi and Haripriya, 2021). Brinjal is often cross pollinated crop and the extent of cross-pollination has been reported as high as 48 per cent (Mishra *et al*., 2023). "Heterostyly" is common feature in multi flower cymes except in bunchy type cultivars. The anthers' cone-like arrangement promotes self-pollination, but because the stigma extends beyond the anthers, it creates ample chances for cross-pollination. In India, there is a growing popularity for brinjal hybrids among farmers and consumers are increasingly drawn to these hybrids because of their early maturation, high yield potential, and exceptional fruit quality in terms of color, shape, and taste. The commercial exploitation of heterosis in brinjal has led to the development of numerous hybrids, employing manual emasculation and pollination techniques. In brinjal cultivation, the success of F_1 hybrids relies on a multitude of factors, including flower characteristics, pollen viability, fruit load per plant, the use of growth regulators, timing of emasculation, pollination, and the ratio of female to male flowers, harvesting stages, and seed extraction methods (Patil *et al*., 2008a). Early pollination with viable pollen can result in poor seed setting due to stigma non-receptivity. Conversely, late pollination can lead to issues caused by drying stigmas or reduced pollen viability. The amount of male pollen deposited on the female stigma is also a crucial determinant in this process in determining F_1 hybrid seed yield. Excessive pollen can lead to competition among germinating grains, potentially reducing seed set. Given these challenges, this research is focused on standardizing techniques for hybrid brinjal seed production, including optimal timing for emasculation, pollination, and the male-to-female flower ratio to enhance fruit set and seed yield.

During the 2019-2020 *kharif* season, an experiment was conducted at Sagdividi Farm, located within the Department of Seed Science and Technology at the College of Agriculture, Junagadh Agricultural University in Junagadh. The investigation encompassed a total of 18 treatment combinations, which included variations in emasculation timing (E_1: Emasculation and pollination on same day, E_2: Emasculation performed one day prior to pollination), pollination time slots during morning time (T_1: 8:00 - 9:00, T_2: 9:00 - 10:00, T_3: 10:00 - 11:00), and different crossing ratios (P_1: One male flower used for pollinating two female flower buds, P_2: One male flower used for pollinating four female flower buds, P_3: One male flower used for pollinating six female flower buds).

The experimental design followed a Randomized Block Design (Factorial), replicated thrice, as per the methodology proposed by Cochran and Cox (1957). The lines used in this experiment were JBR-03-16 as pollen parent and JBR-2-11 as ovule parent. Both were the parental lines of the commercially successful brinjal hybrid namely Gujarat Junagadh Brinjal Hybrid 4 (GJBH 4). Geographically Junagadh is situated at 21.5º N latitude and 70.5º E longitudes with an altitude of 60 meters above the mean sea level. This region enjoys a typical sub tropical climate. The soil of the experimental site was medium black, alluvial in origin and poor in organic matter.

Observation on number of pollinated flowers per plant, the count of successfully cross-fertilized fruits per plant, the percentage of fruit set, fruit weight (in grams), fruit length (in centimeters), fruit girth (in centimeters), mature fruit yield per plant (in grams), the quantity of seeds per fruit, seed weight per fruit (in grams), seed yield per plant (in grams), and test weight (grams) were recorded.

The results of analysis of variance for seed yield and its attributing characters showed that treatments exhibited significant difference for the variables of emasculation timing, pollination time, and the ratio of female to male flower crossing for all seed production yield and its related traits except the count of pollinated flowers per plant. Interaction effects were found non-significant for seed yield and its attributing characters studied (**Table 1a and 1b**).

Impact of the day of emasculation:The quantity of flowers fertilized per female plant was slightly higher (24.98) when emasculation and pollination was performed on the same day (E_1), compared to the emasculation on the previous day (E_2) (23.64). However, emasculation on the previous day of pollination (E2) resulted in significantly better outcomes in terms of the number of successfully cross-fertilized fruits per plant (12.62), fruit set percentage (54.40%), fruit weight (53.07 g), fruit length (11.13 cm), fruit girth (12.47 cm), mature fruit yield per plant (706.58 g), number of seeds per fruit (267.45), seed weight per fruit (1.69 g), seed yield per plant (14.84 g), and test weight (5.21 g) compared to same-day emasculation (E_1) (8.85, 36.00%, 41.31 g, 9.14 cm, 10.98 cm, 387.89 g, 180.73, 0.86 g, 8.27 g, and 4.99 g, respectively) (**Table 1a and 1b**).

Thus, utilizing the "previous day of emasculation" approach (E_2) resulted in noticeably greater numbers of successfully cross-fertilized fruits per plant, greater fruit set percentages, increased fruit weight, longer fruit length, larger fruit girth, higher mature fruit yields per plant, greater numbers of seeds per fruit, increased seed weight per fruit, higher seed yields per plant, and greater test weights compared to the "same day of emasculation" (E_1) method. This outcome aligns with prior findings noted by Jolli *et al.* (2006) in tomato and Priya *et al.* (2009) in chili, where a similar trend was observed regarding the count of hybrid fruits per plant. The drop in fruits when emasculation was immediately followed by pollination could be influenced by the stigma receptivity, though they are most receptive on the day the flower blooms. However, even if pollen falls on the stigma, not all ovules may be fully ready for fertilization yet. This means fewer seeds are formed, leading to fewer fruits. Understanding this process sheds light on how timing affects seed set and fruit production. This finding is consistent with reports by Priya *et al.* (2009) in chilli, as well as Auerswald (1978), Dev (1998), Yogeesha *et al.* (1999), and Patta *et al.* (2015) in tomato. Furthermore, the highest individual fruit weight, longest fruit length, and a greater number of seeds per fruit, along with increased seed yield per plant and test weight, were observed when emasculation was conducted the day before pollination. This could be attributed to the stigma's optimal pollen-receptive state and the full ripeness of ovules during this period. The stigma remains receptive for 4 days, with peak receptivity on the day of anthesis. Similar results were found in chilli by Priya *et al*. (2009).

Influence of Pollination Timing: The quantity of flowers fertilized per female plant showed numerical differences, with higher counts (25.13) observed during pollination at 8:00 to 9:00 am (T_1) and lower counts (23.73) during pollination at 9:00 to 10:00 am (T_2). Among the three different pollination times, the most favorable outcomes were consistently achieved when pollination was done between 9:00 am and 10:00 am (T_2). During this time frame, consistent and significantly higher numbers were recorded for successful fruit set percentages (51.44%), fruit weight (55.31 g), cross-fertilized fruits per plant (11.93), fruit length (10.82 cm), fruit girth (12.80 cm), mature fruit yields per plant (620.91 g), numbers of seeds per fruit (285.60), seed weight per fruit (1.61 g), seed yields per plant (13.78 g), and test weight (5.23 g). In contrast, the least favorable values for these traits were consistently observed when pollination took place between 8:00 am and 9:00 am (T_1) (9.40, 37.99%, 33.72 g, 9.07 cm, 9.94 cm, 449.88 g, 128.51, 0.74 g, 8.02 g, and 4.88 g, respectively) (**Table 1a and 1b**).

Among the three pollination times, the morning period between 9:00 - 10:00 (T_2) exhibited significantly superior outcomes in terms of the number of successfully cross-fertilized fruits per plant, fruit set percentages, fruit length, fruit girth, fruit weight, mature fruit yield per plant, the number of seeds per fruit, seed weight per fruit, seed yield per plant, and test weight. These favorable results can be attributed to optimal environmental conditions, robust pollen viability, and receptive stigmas, all of which contributed to effective fertilization and seed formation. This, in turn, led to increased fertilization rates, higher seed formation, and ultimately greater seed weight per fruit, enhanced seed yield per plant, and improved test weight. These findings align with the research of Petrova *et al.* (1981), Chattopadhyaya (2000), Patil *et al*. (2008b), Korat *et al.* (2018), and Veeresha *et al*. (2018) in brinjal; Hazra *et al*. (2003) and Kumar *et al*. (2008) in tomato; Padda and Singh (1971) in capsicum; and Priya *et al.* (2009) in chilli.

Influence of ratio of female to male flower for crossing: Regardless of the timing of pollination and the day of emasculation, the number of flowers pollinated per female plant exhibited variations. The highest count (24.94) was recorded when each male flower pollinated six female flower buds (P_3), while the lowest count (23.52) was observed when each male flower pollinated two female flower buds (P_1). Similarly, the number of successfully cross-fertilized fruits per plant (11.77), fruit set percentages (50.88%), mature fruit yields per plant (629.21 g), and seed yields per plant (13.37 g) were significantly higher when each male flower pollinated two female flower buds (P_1). Conversely, the lowest numbers of successfully crossed fruits per plant (9.37), fruit set percentages (38.33%), mature fruit yields per plant (433.96 g), and seed yields per plant (9.12 g) were observed when each male flower pollinated six female flower buds (P_3). Additionally, significantly greater fruit weight (50.93 g), fruit length (10.88 cm), fruit girth (12.45 cm), numbers of seeds per fruit (255.12), seed weight per fruit (1.45 g), and test weight (5.22 g) were recorded when each male flower pollinated four female flower buds (P_2). Conversely, significantly lower values for fruit weight (42.44 g), fruit length (9.29 cm), fruit girth (10.89 cm), numbers of seeds per fruit (189.32), seed weight per fruit (1.07 g), and test weight (4.96 g) were observed when each male flower pollinated six female flower buds (P_3) (**Table 1a and 1b**).

The maximum number of successfully cross-fertilized fruits per plant, fruit set percentages, mature fruit yields per plant, and seed yields per plant were significantly achieved when each male flower pollinated two female flower buds (P_1). On the other hand, significantly higher fruit weight, fruit length, fruit girth, numbers of seeds per fruit, seed weight per fruit, and test weight were produced when each male flower pollinated with four female flower buds (P_2). A lower fruit set percentage was observed with a crossing ratio of 6:1 (P_3), likely due to the scarcity of pollen deposition on the stigma of the female flower, potentially leading to flower drop and reduced fruit setting. These findings align with the research conducted by Patil *et al.* (2008b) and Korat *et al.* (2018) in brinjal, Kumar *et al*. (2008) in tomato, and Gowda *et al.* (2017) in okra. The increase in seed yield per plant at the crossing ratio of 2:1 or 4:1 (each male flower pollinated two or four female flower buds) can be attributed to the ample availability of pollen and favorable environmental conditions, facilitating complete fertilization and the development of seeds for all the ovules in the ovary. This results in higher seed weight per fruit, increased seed yield per plant and improved test weight. Conversely, in a higher crossing ratio (6:1), the scarcity of pollen deposited on the stigma of the female flower may lead to flower drop, reduced seed setting, and lower seed yield per plant, consistent with the findings of Patil *et al.* (2008b) and Korat *et al.* (2018) in brinjal, Kumar *et al.* (2008) in tomato, and Gowda *et al.* (2017) in okra.

Combined effect of day of emasculation (E) and time of pollination (T): On average, it was observed a higher count of pollinated flowers per female plant (25.55) during the 8:00 to 9:00 am pollination with emasculation conducted on the same day (E_1T_1). In contrast, a lower count (22.71) was recorded during the 8:00 to 9:00 am pollination with emasculation performed on the previous day (E_2T_1). The maximum number of crossed fruits set per plant (14.02), fruit set (62.51%), fruit weight (62.42 g), fruit length (11.59 cm), fruit girth (13.63 cm), mature fruit yield per plant (811.18 g), number of seeds per fruit (322.67), seed weight per fruit (2.12 g), seed yield per plant (17.50 g), and test weight (5.36 g) were observed when emasculation was conducted the day before pollination, specifically between 9:00 am and 10:00 am (E_2T_2). In contrast, the minimum trait values were consistently observed for same-day emasculation and pollination during the 8:00 to 9:00 am period (E_1T_1) (7.95, 31.55%, 29.06 g, 7.77 cm, 9.50 cm, 318.90 g, 81.22, 0.43 g, 5.30 g, and 4.79 g, respectively).

This favorable outcome of higher fruit set, fruit characteristics, and seed-related traits when emasculation preceded pollination by one day, particularly between 9:00 am and 10:00 am (E2T2), can be attributed to several factors. These include the presence of ripe ovules, optimal environmental conditions, robust pollen viability, and a receptive stigma during this time, which facilitated effective fertilization and seed formation. These findings align with prior research conducted by Priya *et al.* (2009) in chili, underscoring the significance of emasculation timing in achieving optimal yield-related outcomes.

Table 1a. Effect of emasculation day, pollination Timing, and ratio of female to male flower crossings on brinjal pollination and fruit characteristics

Treatments	Number of flowers pollinated per plant	Fruit set in crossed flowers/plant	Fruit set (%)	Fruit weight (g)	Fruit length (cm)
Day of emasculation (E)					
E_1	24.98	8.85	36.00 (36.71*)	41.31	9.14
E_2	23.64	12.62	54.40 (47.67)	53.07	11.13
S. Em±	0.57	0.32	1.03	0.80	0.19
CD at 5 %	NS	0.92	3.00	2.29	0.54
Pollination timing (T)					
T_1	25.13	9.40	37.99 (37.87)	33.72	9.07
T_2	23.73	11.93	51.44 (45.96)	55.31	10.82
T_3	24.08	10.89	46.18 (42.76)	52.55	10.50
S. Em±	0.70	0.39	1.27	0.97	0.23
CD at 5 %	NS	1.13	3.70	2.81	0.66
Ratio of female to male flower crossings (P)					
P_1	23.52	11.77	50.88 (45.58)	48.20	10.22
P_2	24.48	11.08	46.38 (42.92)	50.93	10.88
P_3	24.94	9.37	38.33 (38.08)	42.44	9.29
S. Em±	0.70	0.39	1.27	0.97	0.23
CD at 5 %	NS	1.13	3.70	2.81	0.66
Day of emasculation (E) x Pollination timing(T)					
E_1T_1	25.55	7.95	31.55 (34.00)	29.06	7.77
E_1T_2	24.64	9.84	40.37 (39.40)	48.19	10.05
E_1T_3	24.75	8.77	36.07 (36.74)	46.69	9.60
E_2T_1	22.71	10.84	44.41 (41.74)	38.37	10.38
E_2T_2	22.82	14.02	62.51 (52.52)	62.42	11.59
E_2T_3	23.40	13.00	56.28 (48.76)	58.41	11.40
S. Em ±	0.99	0.55	1.79	1.38	0.33
CD at 5 %	NS	NS	NS	NS	NS
Pollination timing (T) x Ratio of female to male flower crossings (P)					
T_1P_1	24.10	10.53	43.95 (41.38)	34.41	9.12
T_1P_2	25.06	9.40	38.25 (38.13)	37.16	10.04
T_1P_3	26.23	8.26	31.74 (34.10)	29.57	8.06
T_2P_1	23.06	12.76	56.15 (48.83)	56.51	10.88
T_2P_2	23.73	12.40	53.54 (47.16)	59.15	11.43
T_2P_3	24.40	10.63	44.63 (41.85)	50.26	10.17
T_3P_1	23.40	12.01	52.55 (46.51)	53.68	10.66
T_3P_2	24.63	11.43	47.33 (43.43)	56.47	11.17
T_3P_3	24.20	9.20	38.64 (38.31)	47.50	9.67
S. Em±	1.22	0.68	2.20	1.69	0.40
CD at 5 %	NS	NS	NS	NS	NS
Day of emasculation (E) x Ratio of female to male flower crossings (P)					
E_1P_1	23.84	9.47	40.15 (39.18)	42.43	9.29
E_1P_2	25.37	9.60	38.37 (38.23)	45.03	9.74
E_1P_3	25.73	7.49	29.47 (32.72)	36.49	8.38
E_2P_1	23.20	14.06	61.61 (51.96)	53.98	11.15
E_2P_2	23.57	12.55	54.38 (47.61)	56.84	12.00
E_2P_3	24.15	11.24	47.20 (43.45)	48.39	10.21
S. Em±	0.99	0.55	1.79	1.38	0.33
CD at 5 %	NS	NS	NS	NS	NS
Day of emasculation (E) x Pollination timing (T) x Ratio of female to male flower crossings (P)					
$E_1T_1P_1$	23.40	8.33	35.76 (36.50)	29.76	7.81
$E_1T_1P_2$	25.93	9.00	34.82 (36.17)	32.49	8.53
$E_1T_1P_3$	27.33	6.53	24.09 (29.33)	24.95	6.96
$E_1T_2P_1$	23.73	10.47	44.45 (41.80)	49.63	10.13
$E_1T_2P_2$	24.87	10.27	41.96 (40.33)	52.45	10.55
$E_1T_2P_3$	25.33	8.80	34.72 (36.07)	42.50	9.49
$E_1T_3P_1$	24.40	9.63	40.26 (39.27)	47.89	9.93
$E_1T_3P_2$	25.33	9.53	38.33 (38.20)	50.15	10.17
$E_1T_3P_3$	24.53	7.15	29.62 (32.77)	42.04	8.70
$E_2T_1P_1$	24.80	12.73	52.15 (46.27)	39.07	10.44
$E_2T_1P_2$	24.20	9.80	41.69 (40.10)	41.85	11.54
$E_2T_1P_3$	25.13	10.00	39.40 (38.87)	34.20	9.16
$E_2T_2P_1$	22.40	15.07	67.85 (55.87)	63.39	11.62
$E_2T_2P_2$	22.60	14.53	65.14 (54.07)	65.87	12.31
$E_2T_2P_3$	23.47	12.47	54.55 (47.63)	58.01	10.84
$E_2T_3P_1$	22.40	14.40	64.86 (53.77)	59.48	11.40
$E_2T_3P_2$	23.93	13.33	56.34 (48.67)	62.80	12.17
$E_2T_3P_3$	23.87	11.27	47.65 (43.87)	52.97	10.64
Mean	24.31	10.73	45.20 (42.19)	47.19	10.13
S. Em±	1.72	0.96	3.11	2.39	0.56
CD at 5 %	NS	NS	NS	NS	NS
CV %	12.25	15.53	12.78	8.79	9.62

*Figure in parenthesis is Arcsine transformed values

Table 1b. Influence of emasculation day, pollination timing, and ratio of female to male flower crossings on brinjal fruit attributes and seed production

Treatments	Fruit girth (cm)	Mature fruit yield per plant (g)	Number of seeds per fruit	Seed weight per fruit (g)	Seed yield per plant (g)	Test weight (g)
			Day of emasculation (E)			
E_1	10.98	387.89	180.73	0.86	8.27	4.99
E_2	12.47	706.58	267.45	1.69	14.84	5.21
S. Em±	0.24	14.45	7.84	0.04	0.35	0.05
CD at 5 %	0.69	41.52	22.53	0.13	1.02	0.15
			Pollination timing (T)			
T_1	9.94	449.88	128.51	0.74	8.02	4.88
T_2	12.80	620.91	285.60	1.61	13.78	5.23
T_3	12.45	570.93	258.17	1.47	12.87	5.18
S. Em±	0.29	17.69	9.60	0.05	0.43	0.06
CD at 5 %	0.85	50.85	27.59	0.16	1.24	0.18
			Ratio of female to male flower crossings (P)			
P_1	11.83	629.21	227.83	1.30	13.37	5.12
P_2	12.45	578.55	255.12	1.45	12.18	5.22
P_3	10.89	433.96	189.32	1.07	9.12	4.96
S. Em±	0.29	17.69	9.60	0.05	0.43	0.06
CD at 5 %	0.85	50.85	27.59	0.16	1.24	0.18
			Day of emasculation (E) x Pollination timing (T)			
E_1T_1	9.50	318.90	81.22	0.43	5.30	4.79
E_1T_2	11.95	430.64	248.52	1.11	10.07	5.09
E_1T_3	11.48	414.14	212.45	1.04	9.44	5.08
E_2T_1	10.37	580.85	175.79	1.05	10.73	4.98
E_2T_2	13.63	811.18	322.67	2.12	17.50	5.36
E_2T_3	13.40	727.71	303.88	1.90	16.29	5.27
S. Em±	0.42	25.02	13.57	0.08	0.61	0.09
CD at 5 %	NS	NS	NS	NS	NS	NS
			pollination timing (T) x Ratio of female to male flower crossings (P)			
T_1P_1	10.15	528.69	136.11	0.76	9.66	4.88
T_1P_2	10.95	471.21	151.07	0.88	8.23	4.94
T_1P_3	8.69	349.73	98.34	0.56	6.16	4.83
T_2P_1	12.87	695.38	291.80	1.69	16.17	5.26
T_2P_2	13.34	657.91	324.12	1.80	13.91	5.37
T_2P_3	12.16	509.44	240.87	1.35	11.28	5.06
T_3P_1	12.46	663.57	255.59	1.45	14.28	5.21
T_3P_2	13.05	606.52	290.16	1.67	12.4	5.35
T_3P_3	11.82	442.69	228.74	1.30	9.92	4.99
S. Em±	0.51	30.65	16.63	0.10	0.75	0.11
CD at 5 %	NS	NS	NS	NS	NS	NS
			Day of emasculation (E) x Ratio of female to male flower crossings (P)			
E_1P_1	11.20	448.36	182.34	0.86	9.86	5.01
E_1P_2	11.52	415.12	215.19	1.03	7.93	5.05
E_1P_3	10.21	300.20	144.64	0.68	6.59	4.91
E_2P_1	12.46	810.06	273.31	1.74	17.88	5.22
E_2P_2	13.37	741.98	295.04	1.87	14.76	5.39
E_2P_3	11.57	567.71	233.99	1.45	11.54	5.00
S. Em±	0.42	25.02	13.57	0.08	0.61	0.09
CD at 5 %	NS	NS	NS	NS	NS	NS
			Day of emasculation (E) x Time of pollination (T) x Ratio of female to male flower crossings (P)			
$E_1T_1P_1$	9.94	373.57	87.77	0.45	6.34	4.78
$E_1T_1P_2$	10.33	361.31	93.27	0.52	5.65	4.82
$E_1T_1P_3$	8.23	221.83	62.61	0.31	3.92	4.76
$E_1T_2P_1$	12.10	480.36	257.34	1.16	11.48	5.19
$E_1T_2P_2$	12.35	443.35	286.07	1.29	10.22	5.11
$E_1T_2P_3$	11.42	368.20	202.14	0.86	8.52	5.00
$E_1T_3P_1$	11.56	491.16	201.93	0.96	10.42	5.09
$E_1T_3P_2$	11.90	440.69	266.23	1.30	10.58	5.21
$E_1T_3P_3$	11.00	310.58	169.18	0.86	7.32	4.97
$E_2T_1P_1$	10.37	683.81	184.44	1.07	12.99	4.99
$E_2T_1P_2$	11.58	581.11	208.87	1.26	10.80	5.05
$E_2T_1P_3$	9.16	477.64	134.07	0.81	8.40	4.90
$E_2T_2P_1$	13.66	910.41	326.25	2.22	20.85	5.34
$E_2T_2P_2$	14.34	872.47	362.17	2.30	17.60	5.57
$E_2T_2P_3$	12.91	650.69	279.61	1.83	14.03	5.11
$E_2T_3P_1$	13.37	835.98	309.25	1.93	18.14	5.33
$E_2T_3P_2$	14.20	772.36	314.09	2.05	18.22	5.48
$E_2T_3P_3$	12.64	574.80	288.31	1.73	12.52	5.01
Mean	11.72	547.24	224.09	1.27	11.56	5.09
S. Em±	0.72	43.34	23.52	1.13	1.06	0.15
CD at 5 %	NS	NS	NS	NS	NS	NS
CV %	10.65	13.71	18.18	18.3	15.91	5.25

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Combined influence of the timing of pollination (T) and ratio of female to male flowers in cross-pollination process (P): Comparatively, higher flower pollination rates per female plant (26.23) were observed when six female flowers were fertilized by each male flower during the morning 8:00 - 9:00 period (T_1P_3), whereas lower rates (23.06) were recorded during morning 9:00 - 10:00 Each male flower pollinated two female buds. (T_2P_1). Conversely, the fruit set parameters exhibited a different trend, with higher rates of crossed fruits set per plant (12.76), fruit set (56.15%), mature fruit yield per plant (695.38 gram), and seed yield per plant (16.17 gram) when Each male flower pollinated two female flower buds during morning 9:00 - 10:00 time (T_2P_1). Lower rates (8.26, 31.74%, 349.73 g, and 6.16 g, respectively) were recorded when each male flower pollinated six female flower buds during morning time 8:00 - 9:00 (T_1P_3).

Focusing on fruit characteristics, the highest values for weight of fruit(59.15 g), length of fruit (11.43 cm), girth of fruit (13.34 cm), number of seeds per fruit (324.12), per fruit seed weight (1.80 g), and test weight (5.37 g) were observed when each male flower pollinated four female flower buds during morning time 9:00 - 10:00 am (T_2P_2). In contrast, the lowest values for these traits were recorded when each male flower pollinated six female flower buds during morning time 8:00 - 9:00 (T_1P_3) (29.57 g, 8.06 cm, 8.69 cm, 98.34, 0.56 g, and 4.83 g, respectively).

The interactions between the point in time when pollination occurs (T) and ratio of female-to-male flower crossings (P) played a significant role in the results. Specifically, when pollinating between morning time 9:00 - 10:00am with each male flower pollinated two female flower buds (T_2P_1), there were higher numbers of successfully cross-fertilized fruits per plant, higher fruit set percentages, mature fruit yields per plant, and seed yields per plant. In contrast, these values were lower when pollinating between morning time 8:00 - 9:00 with each male flower pollinated six female flower buds (T_1P_3). For other fruit attributes, the highest values consistently emerged when each male flower pollinated four female flower buds between 9:00 - 10:00 (T_2P_2). Conversely, the lowest values for these traits were consistently recorded when pollinating between morning time 8:00 - 9:00 am with each male flower pollinated six female flower buds (T_1P_3). These observations align with previous research in brinjal and tomato, reinforcing the impact of timing and flower ratios on various yield-related factors as reported by Patil *et al*. (2008b), Kumar *et al*. (2008) and Korat *et al*. (2018).

Impact of combined effect of day of emasculation (E) and the ratio of female-to-male flower crossings (P):In terms of numerical observations, a higher count of pollinated flowers per female plant (25.73) was observed when emasculation and pollination occurred on the same day with each male flower pollinated six female flower buds (E_1P_3). Conversely, a lower count (23.20) was recorded when emasculation was done on the previous day and each male flower pollinated two female flower buds (E_2P_1). When each male flower pollinated two female flower buds on the previous day of emasculation (E_2P_1), higher figures for crossed fruits set per plant (14.06), fruit set percentage (61.61%), mature fruit yield per plant (810.06 g) and seed yield per plant (17.88 g) was observed. In contrast, these metrics were lower (7.49, 29.47%, 300.20 g, and 6.59 g, respectively) when each male flower pollinated six female flower buds on the same day of emasculation (E_1P_3).

Regarding fruit characteristics, higher values in terms of fruit weight (56.84 g), fruit length (12.00 cm), fruit girth (13.37 cm), number of seeds per fruit (295.04), seed weight per fruit (1.87 g), and test weight (5.39 g) were recorded when each male flower pollinated four female flower buds on the previous day of emasculation (E_2P_2). Conversely, the lowest values for these traits were observed in the case of each male flower pollinated six female flower buds on the same day of emasculation (E_1P_3) (36.49 g, 8.38 cm, 10.21 cm, 144.64, 0.68 g, and 4.91 g, respectively).

Notably, the interaction between the day of emasculation (E) and the female-to-male flower crossing ratio (P) had a significant impact on the results. The highest numbers of successfully cross-fertilized fruits per plant, fruit set percentages, mature fruit yields per plant, and seed yields per plant were consistently observed when each male flower pollinated two female flower buds on the previous day of emasculation (E_2P_1). Conversely, these values were consistently lower when each male flower pollinated six female flower buds on the same day of emasculation (E_1P_3). Regarding other fruit attributes peak values were consistently recorded when each male flower pollinated four female flower buds on the previous day of emasculation (E_2P_2). Conversely, the lowest values for these traits were consistently observed when each male flower pollinated six female flower buds on the same day of emasculation (E_1P_3). These discoveries align with prior research in brinjal and tomato, particularly in terms of fruit set percentages, as reported by Patil *et al*. (2008b), Venudevan *et al.* (2011), Korat *et al*. (2018), and Kumar *et al*. (2008).

Combined influence of the day of emasculation (E), the timing of pollination (T), and the female-to-male flower crossing ratio (P): Significant variations in the number of flowers pollinated, fruit set percentages, and yield-related traits based on different emasculation and pollination timings was observed in the study. The highest number of flowers pollinated per female plant occurred when each male flower pollinated six female flower buds during the same day of emasculation ($E_1T_1P_3$), while the lowest number was observed each male flower pollinated two female flower buds, with emasculation done on the previous day ($E_2T_3P_1$ and $E_2T_2P_1$).

The most promising results were consistently obtained in the $E_2T_2P_1$ group, where each male flower pollinated two

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female flower buds on the previous day of emasculation between morning time 9:00 - 10:00 am. These set of treatments exhibited the highest number of successfully cross-fertilized fruits per plant, fruit set percentages, mature fruit yields per plant, and seed yields per plant. Furthermore, the treatment set $E_2T_2P_2$, involving one male flower pollinating four female flower buds on the day prior to emasculation between 9:00 am and 10:00 am, consistently produced fruits with superior weight, length, girth, and seed-related characteristics.

These findings suggest that the timing of emasculation and pollination played a crucial role in achieving optimal fruit production and seed yield in brinjal cultivation. Specifically, using one male flower to pollinate two female flower buds, with emasculation carried out on the previous day between 9:00 am and 10:00 am, emerges as the most effective strategy for maximizing yield and fruit quality. Study underscores the vital significance of timing and cross-pollination techniques in improving seed yield in F_1 hybrid brinjal varieties. These findings have direct implications for the efficiency and sustainability of hybrid seed production, offering practical insights for seed sector. By optimizing emasculation and pollination timing, as well as the male to female flower ratio, significant improvements in seed yield can be achieved, contributing to enhanced agricultural productivity and food security.

The findings highlight the importance of the day of emasculation, time of pollination, and gender ratio in flower crosses in optimizing seed yield in brinjal hybrid seeds. The study demonstrates that emasculation on the previous day and pollinating between 9:00 am and 10:00 am of the next day using either each male flower pollinated two or four female flower buds (2:1 or 4:1), consistently recorded superior triats in terms of fruit set percentage and associated yield factors, and seed yield. This combination represents the most effective strategy for achieving higher seed yield per plant and overall improved yield-related traits in hybrid brinjal cultivation.

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