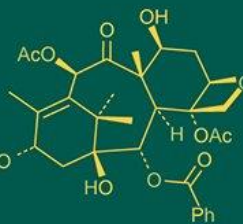
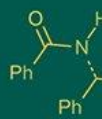
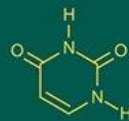
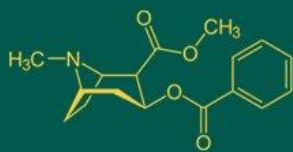


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Influence of pollination on fruit set and fruit traits in custard apple (*Annona squamosa* L.) genotypes

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Abstract

The present study was carried out at the Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India, during year 2023-24 with Completely Randomized Design with three Factorial concept having three repetitions and nine treatments combinations of two factors. Genotype (G₁: Anand selection-1, G₂: Sindhan, G₃: Balanagar and Levels of pollen grain (P₁: Natural pollination, P₂: Hand pollination with 100% pollen grain and P₃: Hand pollination with 40% pollen grain + 60% corn starch). The treatments were repeated three times. Among different genotypes, Balanagar recorded significantly maximum fruit retention at pea stage (43.54%), fruit retention at marble stage (42.43%), fruit diameter (7.84 cm), fruit weight (217.19 g), rind weight (115.73 g) in pooled data. In quality parameters, higher total sugars (23.54%), Reducing sugars (17.71%), non-reducing sugar (5.79%) was recorded with Balanagar during the pooled analysis. From the two years of experiment, it can be concluded that the Balanagar cultivar exhibited superior fruit set, higher fruit contributing traits and fruit quality parameters. Significant variation was observed among different pollination methods for quantitative and qualitative traits. Hand pollination using 100% pollen grain performed better than other treatments across most parameters while, natural pollination showed lower outcomes.

Keywords: Balanagar, custard apple, genotypes, hand pollination, pollination, pollen grain level, total sugars

Introduction

Custard apple (*Annona squamosa* L.) is a commercially and nutritionally important fruit. Its edible pulp is soft, creamy-granular, juicy, and pleasantly sweet with mild acidity, making it suitable for products such as custard powder, frozen pulp, and beverages (Khodifad *et al.*, 2016) [16]. Proximate composition (per serving as reported) includes moisture 70.5 g, protein 1.6 g, fat 0.4 g, minerals 0.9 g, fiber 3.1 g, calcium 17.0 mg, phosphorus 47.0 mg, iron 1.5 mg, thiamine 0.07 mg, riboflavin 0.17 mg, niacin 1.30 mg, vitamin C 37.0 mg, and energy 104 kcal (Gopalan *et al.*, 1987) [13]. *Annona* species flower on current-and previous-season shoots (rarely on older wood). Flowers form a three-petaled floral chamber enclosing numerous organs; they are hermaphroditic and protogynous, with stigmas receptive up to ~24 h (Gazit *et al.*, 1982) [8], favoring cross-pollination. In custard apple, flowering extends from March to April and July to August (peak April-May), but effective fruit set typically begins only with the onset of the rainy season. One of the primary challenges in expanding the commercial cultivation of annonaceous fruits is their low productivity (Hayes, 1957; George and Nissen, 1986) [14, 10]. Although custard apple plants produce a sufficient number of flowers to support a good harvest, poor fruit set results in low yields. Under natural conditions, fruit set rates as low as 1% to 8% have been reported (Ahmad, 1936; Venkataratnam, 1963; Thakur and Singh, 1965; Kumar *et al.*, 1977; George and Nissen, 1988) [1, 33, 31, 19]. In custard apple flowers, the occurrence of protogynous dichogamy significantly limits the possibility of self-pollination. This is because the stigma reaches receptivity well before the anthers release pollen, thereby creating a temporal separation between female and male fertility within the same flower. (Campbell and Phillips, 1994) [4]. While the plant produces a large number of hermaphroditic, self-fertile flowers, only 1 or 2% of these flowers successfully develop into fruits due to this phenomenon.

As a result, achieving economic yields is not feasible without assisted pollination, as relying solely on natural pollination is insufficient. Hand-pollinated fruits, however, often command premium prices in the market due to their superior quality (Campbell and Phillips, 1994; Jalikop and Kumar, 2007; Campos *et al.*, 2004; Escobar *et al.*, 1986; Melo *et al.*, 2004; Matsuda and Higuchi, 2019; Motis, 2007) [4, 15, 5, 7, 20, 23]. Manual pollination has to be a highly effective technique, not only enhancing fruit set but also contributing to the development of larger, more visually appealing, and uniformly shaped fruit.

Materials and Methods

The experiment was carried out at Horticultural Research Farm, Department of Horticulture, B. A. College of Agriculture, Anand Agricultural University, Anand during the year 2023 and 2024 on thirteen-year-old guava plants of genotypes Anand Selection-1, Sindhan and Balanagar. Every plant that was selected had a similar development pattern to genotypes and all cultural practices aside from treatment was administered to each plant in the same way. The experiment was laid out in Completely Randomized Design with Factorial concept having three repetitions and nine treatment combinations of three factors. A.) Genotype (G₁: Anand selection-1, G₂: Sindhan, G₃: Balanagar B.) Levels of pollen grain (P₁: Natural pollination, P₂: Hand pollination with 100% pollen grain and P₃: Hand pollination with 40% pollen grain + 60% corn starch). All the selected plants were almost uniform in growth and vigour and were given uniform cultural operations. Observations were recorded during experimentation. Statistical analysis was done by using method of analysis of variance (ANOVA) for Completely Randomized Design with Factorial concept by Gomez and Gomez (1976) [12].

Results and Discussion

The results revealed that among different genotypes Balanagar (G₃), exhibit Significantly high fruit retention at pea stage (43.08, 44.00 and 43.54%), fruit retention at marble stage (41.69, 43.18 and 42.43%), maximum fruit diameter (7.82, 7.87 and 7.84 cm), higher fruit weight (214.52, 219.86 and 217.19 g), higher rind weight (113.70, 117.76 and 115.73 g) higher total sugar (23.49, 23.60 and 23.54%), higher reducing sugars (17.66, 17.72 and 17.71%) during the year 2023, 2024 and pooled analysis, respectively. It might be due to genetic difference among the genotypes. This results in the maximum fruit diameter might be due to genetic differences among the genotypes might be responsible for the observed variation as traits, such as ovary size, ovule fertility, nutrient allocation and responsiveness to pollination can significantly influence the final fruit diameter. Higher fruit and rind weight might be due to fruit weight of Balanagar was highest as compared to other genotypes. Similar results were obtained by Rao and Subramanyam (2011) [25] and Bagul and Masu (2017) [2] in custard apple.

Among the different level of pollen grain the highest fruit retention at pea stage (57.62, 58.55 and 58.08%) was recorded in hand pollination with 100% pollen grain (P₂), highest fruit retention at marble stage (56.40, 57.63 and 57.01%) This could be attributed to the protogynous nature of the flower, where the stigma becomes receptive before the anthers release pollen. The results are in agreement with those found Sanghani and Varu (2022) [27], Thakur and Singh (1964) [30], George *et al.* (1989) [9] and Kishor *et al.* (2012) [18]. The maximum fruit diameter was recorded in hand pollination with 100% pollen grain (8.03, 8.13 and 8.08 cm) in both the years, 2023, 2024 and pooled data. It might be due to a high concentration of viable pollen is manually deposited onto the stigmas at the peak of receptivity, overcoming the limitations of natural pollination such as inadequate pollen transfer, pollinator scarcity, and floral protogyny. The results were in accordance with the findings of Sanghani and Varu (2022) [27] and Pereira *et al.* (2019) [24] in custard apple, Melo *et al.* (2004) [22] in atemoya and Boraiah *et al.* (2024) [3] in dragon fruit. The maximum fruit weight (221.86, 226.30 and 224.07 g), maximum Pulp weight (84.92, 87.09 and 86.00 g) and maximum rind weight (117.59, 120.94 and 119.26 g) in hand pollination with 100% pollen grain during both the years, 2023, 2024 and pooled data. This might be due to pollen grains were directly and uniformly applied to all receptive stigmas, ensuring complete ovule fertilization. This promotes optimal seed set, which in turn stimulates the release of growth hormones such as auxins, gibberellins, and cytokinins from developing embryos and endosperm. These hormones play a critical role in stimulating cell division and cell enlargement in the ovary wall, leading to enhanced pericarp development and increased fruit biomass. In contrast, natural pollination often suffers from low pollen transfer efficiency, asynchronous flower receptivity and inadequate pollinator activity especially in protogynous condition resulting in partial fertilization, lower seed number, and ultimately reduced fruit weight. The results were in accordance with Sanghani and Varu (2022) [27] and Pereira *et al.* (2019) [24] in custard apple, Schroeder (1941) [28] and Richardson and Anderson (1995) [26] in cherimoya, Melo *et al.* (2004) [22] in atemoya, Shaaban *et al.* (2019) [29] in datepalm, Usman *et al.* (2013) [32] in guava, King and Ferguson (1991) [17] in kiwi, Boraiah *et al.* (2024) [3] in dragon fruit and Usman *et al.* (2013) [32] in guava. The higher total sugars (23.49, 23.60 and 23.54%), higher Reducing sugars (17.66, 17.72 and 17.71%) in hand pollination with 100% pollen grain (P₂), recorded in both the years, 2023, 2024 and pooled data. This might be due to the much variation in the reducing and nonreducing sugar which leads to variation in the total sugar. Similar results were obtained by Sanghani and Varu (2022) [27] and Meena *et al.* (2023) [21] in cu stard apple, Eassa *et al.* (2012) [6] and Usman *et al.* (2013) [32] in guava and Munir *et al.* (2020) in date palm.

Table 1: Effect of genotype, level of pollen grain on fruit retention at pea stage, fruit retention at marble stage and fruit diameter in custard apple

Code	Treatment Details	Fruit retention at pea stage (%)			Fruit retention at marble stage (%)			Fruit diameter (cm)		
		2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Genotypes (G)										
G ₁	Anand Selection-1	38.16	39.08	38.62	36.77	37.61	37.19	7.31	7.38	7.35
G ₂	Sindhhan	41.82	42.74	42.28	40.32	41.70	41.01	7.51	7.64	7.57
G ₃	Balanagar	43.08	44.00	43.54	41.69	43.18	42.43	7.82	7.87	7.84
S. Em. ±		0.88	0.91	0.63	0.79	0.92	0.60	0.13	0.13	0.10
C. D. (P = 0.05)		2.62	2.70	1.82	2.36	2.72	1.74	0.38	0.38	0.26
Level of pollen grain (P)										
P ₁	Natural pollination (Control)	26.09	27.02	26.55	24.87	25.38	25.13	7.09	7.22	7.16
P ₂	Hand pollination with 100% pollen grain	57.62	58.55	58.08	56.40	57.63	57.01	8.03	8.13	8.08
P ₃	Hand pollination with 40% pollen grain + 60% corn starch	39.34	40.27	39.80	37.50	39.49	38.50	7.51	7.55	7.53
S. Em. ±		0.88	0.91	0.63	0.79	0.91	0.61	0.13	0.13	0.10
C. D. (P = 0.05)		2.62	2.70	1.82	2.36	2.72	1.74	0.38	0.38	0.26
Year		-	-	NS	-	-	NS	-	-	NS
Significant interaction		-	-	-	-	-	-	-	-	-
C.V.%		6.46	6.51	6.49	6.03	6.73	6.40	5.11	5.05	5.06

Table 2: Effect of genotype, level of pollen grain on fruit weight and rind weight in custard apple

Code	Treatment Details	Fruit weight (g)			Rind weight (g)		
		2023	2024	Pooled	2023	2024	Pooled
Genotypes (G)							
G ₁	Anand Selection-1	196.79	198.78	197.78	104.30	106.41	105.36
G ₂	Sindhhan	206.92	210.26	208.59	109.67	111.96	110.82
G ₃	Balanagar	214.52	219.86	217.19	113.70	117.76	115.73
S. Em. ±		3.88	3.72	2.69	1.87	2.07	1.40
C. D. (P = 0.05)		11.51	11.05	7.70	5.56	6.15	4.00
Level of pollen grain (P)							
P ₁	Natural pollination (Control)	187.70	190.60	189.15	99.48	102.61	101.04
P ₂	Hand pollination with 100% pollen grain	221.86	226.30	224.07	117.59	120.94	119.26
P ₃	Hand pollination with 40% pollen grain + 60% corn starch	208.69	212.00	210.33	110.60	112.61	111.65
S. Em. ±		3.88	3.72	2.69	1.87	2.07	1.40
C. D. (P = 0.05)		11.51	11.05	7.70	5.56	6.15	4.00
Year		-	-	NS	-	-	NS
Significant interaction		-	-	-	-	-	-
C.V.%		5.64	5.32	5.48	5.14	5.54	5.35

Table 3: Effect of genotype, level of pollen grain on total sugars and reducing sugar in custard apple

Code	Treatment Details	Total sugars (%)			Reducing sugar (%)		
		2023	2024	Pooled	2023	2024	Pooled
Genotypes (G)							
G ₁	Anand Selection-1	21.43	21.53	21.48	16.11	16.17	16.14
G ₂	Sindhani	22.50	22.57	22.54	16.98	17.06	17.01
G ₃	Balanagar	23.49	23.60	23.54	17.66	17.72	17.71
S. Em. ±		0.33	0.34	0.23	0.24	0.26	0.18
C. D. (P = 0.05)		0.97	1.00	0.67	0.72	0.77	0.51
Level of pollen grain (P)							
P ₁	Natural pollination (Control)	21.12	21.21	21.17	15.96	16.01	15.99
P ₂	Hand pollination with 100% pollen grain	24.06	24.17	24.11	18.12	18.23	18.17
P ₃	Hand pollination with 40% pollen grain + 60% corn starch	22.24	22.32	22.28	16.67	16.71	16.69
S. Em. ±		0.33	0.34	0.23	0.24	0.26	0.18
C. D. (P = 0.05)		0.97	1.00	0.67	0.72	0.77	0.51
Year		-	-	NS	-	-	NS
Significant interaction		-	-	-	-	-	-
C.V.%		4.38	4.46	4.42	4.27	4.59	4.43

Conclusion

From the two years of field experiment, it can be concluded that the Balanagar cultivar exhibited superior fruit set, higher fruit contributing quantitative traits and fruit qualitative traits. Significant variation was observed among

different pollination methods for quantitative and qualitative traits. Hand pollination using 100% pollen grain performed better than other treatments across most parameters while, natural pollination showed lower outcomes.

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