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Effect of different pollination methods on fruit set and yield in custard apple cv. Sindhan (*Annona squamosa* L.)

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Abstract
The present investigation was carried out at Fruit Research Station, Madhavbaug, Junagadh Agricultural University, Junagadh during the year 2021. The results revealed that the maximum fruit set at pea stage (72.68%), maximum fruit set at marble stage (71.26%), highest numbers of fruit set per shoot (8.67), maximum fruit length (8.81 cm), maximum fruit diameter(8.92 cm), maximum fruit weight (399.67g) and maximum pulp weight (191.33 g) were recorded in hand pollination with 100% pollen using paint brush (T3). minimum peel weight (85.33 g) and minimum seed weight (22.00 g) were recorded in hand pollination with 40% pollen + 60% corn starch using sprayer (T10), minimum number of seeds per fruit (39.00) was noted in natural pollination (T1), minimum stone fruit (1.70%) was recorded in hand pollination with 40% pollen+ 60% corn starch using paint brush (T6). For yield parameters, maximum number of fruits per plant (433.33), highest estimated yield (86.6kg/plant) and (24 t/ha) were recorded in hand pollination with 100% pollen using paint brush (T3) followed by hand pollination with 100% pollen using sprayer (T7).

Keywords: Custard apple, hand pollination, fruit set, fruit characteristics, yield, quality

Introduction
Custard apple (*Annona squamosa* L.) is the most widely cultivated species in India and probably in the tropics of the world. It is popularly known as custard apple, sweetsop and in the Northern India Sharifa, while in Southern part sitaphal. Custard apple is an arid fruit crop and hardy in nature requires dry climate with mild winter. Custard apple is known in India since era with legendary names of Ramayana too. It is also known as sugar apple belongs to the family Annonaceae. The Annonaceae or custard apple family comprises about 120 genera and more than 2000 species (Leboeuf *et al*., 1982) [17]. The total area under cultivation of custard apple in India is around 40,000 ha and the production was 3,39, 000 MT. In Gujarat, the area, production and productivity are 5126 hector, 55541 MT and 10.84 ton/ha, respectively (Anon., 2018-19). In Gujarat, it is cultivated in Junagadh and Bhavnagar districts of Saurastra region. Area under custard apple is also increasing in other district like Ahmadabad, Sabarkantha, Banashkantha, Gandhinagar, Anand and Patan.

Custard apple is an aggregate fruit which is developed from a single flower that has multiple pistils, each containing one carpel. Each pistil forms a fruitlet. Together, the fruitlets are called an aggregate or an etaerio. Aggregate fruits can be etaerio of achenes, drupes or berries. Custard apple bear aggregates of berries. Low productivity of annonaceous fruits is the main constraint in expanding their commercial cultivation (Hayes, 1957 [34]: George and Nissen, 1986) [9]. Enough flowers are born on a custard apple plant to give a good crop but the poor fruit set causes low yield. Only one to eight percent fruit set has been reported under natural conditions (Ahmad, 1936; Venkataratnam, 1963; Thakur and Singh, 1965b; Kumar *et al*., 1977; George and Nissen, 1988) [35, 32, 29, 16, 10].

The low fruit set in custard apple is due to poor pollination which has been attributed to both the external and internal factors, such as very high and low humidity prevailing at the time of flowering, soil moisture stress, competition between vegetative and floral growth, hypogyny, Protogynous Dichogamy, poor pollen germination and lack of insect pollinators. Protogynous dichogamy phenomenon exists in the flower that is why self-pollination is nearly impossible because the stigma becomes receptive or viable long before the pollen is released (Campbell and Phillips, 1994). This produces large number of hermaphrodite self-fertile flowers but only 1-2% flowers convert into fruits due to Protogynous Dichogamy.

Besides, it doesn't attract insects which could help in pollination. Hence, one cannot justify the yield without assisted pollination and cannot rely completely on natural pollination to get economic yield. Hand pollination is an effective approach which helps not only in good fruit set but also produces big size, attractive uniform shape fruits with no loss in edible attributes.

Materials and Methods

An investigation was conducted at Madhavbaug, Fruit Research Station, Department of Horticulture, Junagadh Agricultural University, Junagadh during the year 2021. The treatment comprises of ten different pollination methods with three replications and laid out in Randomized Block design (RBD), 20 years old tree with 6m x 6m spacing. For this studies, flowers were collected a day before pollination at evening time between 5.00 to 6.00 pm. Then flowers were dried at room temperature (average 26˚C) until release pollen grain. The flowers were also placed under sun to induce maximum dehiscence. For each replication, a minimum number of 30 flowers are required. Pollens were collected from previously dried flowers at the day of pollination in morning time by shaking the flowers in petri dish or by using paint brush. The application of pure or mixed pollen was done on the carpel of open flowers when they presented with a humid aspect and bright, indicating its receptivity. Pollination was done in morning hours before 9.00 am. In brush treatments two applications were made to the carpel of the flower. For sprayer, pure pollen or mixed pollen were diluted in water before pollination and make a pollen suspension in sprayer bottle. For each flower two spray of pollen is required. After pollination flowers were tagged and noted date of pollination.

Fig 1: Method of Pollen collection

Results and Discussion

Fruiting parameter and yield parameter of different pollination methods in custard apple is mentioned in Table 1 and Table 2.

Fruit set at pea stage (%)

The maximum fruit set at pea stage (72.68%) was noted in hand pollination with 100% pollen using paint brush (T3). However, it was at par with the hand pollination with 100% pollen using sprayer (T7). While, the lowest fruit set at pea stage (2.15%) was observed in self- pollination (T2). The results obtained are similar to those obtained by Thakur and Singh (1965a) [29], Rao (1974) [23], Cogez and Lyannaz (1994) [5], Campos *et al*. (2004) [4], Pinto *et al*. (2005) [21], Vinay *et al*. (2017) [14], Hansraj Meena (2020) [13]. The variation in different treatment might be due to proper fertilization and pollen tube germination in more number of flowers with paint brush or spray compared to natural pollination or self – pollination.

Fruit set at marble stage (%)

The result was found significant and maximum fruit set at marble stage (71.26%) was also reported in hand pollination with 100% pollen using paint brush (T3) and was at par with hand pollination with 100% pollen using sprayer (T7) and hand pollination with 80% pollen + 20% corn starch using paint brush (T4). While, minimum fruit set at marble stage (1.91%) noted in self- pollination (T2). This might be due to proper fertilization and pollen tube germination and strong pedicel attachment which prevent fruit drop at pea stage. The results are in agreement with those found by Pinto *et al.* (2005) [21], Pritchard and Edwards (2006) [22], Schroeder (1941) [21] in cherimoya.

Number of fruit set/shoot

Significantly highest number of fruit set per shoot (8.67) was recorded in hand pollination with 100% pollen using paint brush (T3) followed by hand pollination with 100% pollen using sprayer (T7). Minimum number of fruit set per shoot (0.20) was recorded in self- pollination (T2). The results are in accordance with the finding of Thakur and Singh (1965) [28], Campos *et al.* (2004) [4], Jalikop and Ravindra Kumar (2007) [15] and Schroeder (1941) [27] in cherimoya.

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Table 1: Effect of different pollination methods on fruiting parameter of custard apple cv. Sindhan

Sr. No.	Treatment details	Fruit set at pea stage (%)	Fruit set at marble stage (%)	No. of fruit set/shoot	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)
T1	Natural pollination	21.39	19.60	1.75	6.44	7.69	214.00
T2	Self- pollination	2.15	1.91	0.20	6.55	6.62	217.67
T3	Hand pollination with 100% pollen using paint brush	72.68	71.26	8.67	8.81	8.92	399.67
T4	Hand pollination with 80% pollen+ 20% corn starch using paint brush	65.70	65.20	7.07	8.22	8.57	373.67
T5	Hand pollination with 60% pollen+ 40% corn starch using paint brush	62.33	61.60	6.23	7.81	8.32	325.00
T6	Hand pollination with 40% pollen+ 60% corn starch using paint brush	58.73	58.00	6.50	6.42	8.04	265.00
T7	Hand pollination with 100% pollen using sprayer	69.03	68.33	7.60	8.61	8.19	375.00
T8	Hand pollination with 80% pollen+ 20% corn starch using sprayer	55.67	54.53	5.00	8.50	8.42	344.67
T9	Hand pollination with 60% pollen + 40% corn starch using sprayer	60.95	60.70	5.17	7.00	7.27	320.00
T10	Hand pollination with 40% pollen+ 60% corn starch using sprayer	54.81	53.67	4.70	6.64	7.41	206.00
S.Em.±		2.31	2.26	0.12	0.17	0.21	5.47
C.D. at 5%		6.85	6.73	0.36	0.50	0.62	16.24
C.V. %		7.63	7.62	3.97	3.89	4.58	3.11

Fruit length (cm)

Maximum fruit length (8.81 cm) was observed in hand pollination with 100% pollen using paint brush (T3). However, it was at par with the hand pollination with 100% pollen using sprayer (T7) and hand pollination with 80% pollen + 20% corn starch using sprayer (T8). While, lowest fruit length (6.44 cm) was observed in natural pollination (T1). The similar reports were observed by Pinto *et al*. (2005) [21], Pritchard and Edwards (2006) [22], Jalikop and Ravindra Kumar (2007) [15].

Fruit diameter (cm)

The variation due to different treatments was also found significant. The result showed that the maximum fruit diameter (8.92 cm) was noted in hand pollination with 100% pollen using paint brush (T3) and it was at par with hand pollination with 80% pollen + 20% corn starch using paint brush (T4), hand pollination with 80% pollen + 20% corn starch using sprayer (T8) and hand pollination with 60% pollen + 40% corn starch using paint brush (T5). Likewise, minimum fruit diameter (6.62 cm) was recorded in self-pollination (T2). This might be due to better distribution of pollen on all the stigmas of the female flowers more than to an additional contribution of pollen. Such type of variability was recorded by Hansraj Meena (2020) [13], Usman *et al*. (2013) [31] in guava, Ullah *et al*. (2018) [30] in date palm and Nor *et al*. (2019) [20] in apple.

Fruit weight (g)

Maximum fruit weight (399.67g) was observed in hand pollination with 100% pollen using paint brush (T3) followed by hand pollination with 100% pollen using sprayer (T7). Whereas, lowest fruit weight (214 g) was recorded in natural pollination (T1). In conformity with the similar variations observed by Cogez and Lyannaz (1994) [5], Jalikop and Ravindra Kumar (2007) [15], Hansraj Meena (2020) [13], Saleh *et al.* (2014) [26], Ullah *et al*. (2018) [30] and El-Sharabasy *et al.* (2020) [7] in date palm.

Pulp weight (g)

Maximum pulp weight (191.33 g) was observed in hand pollination with 100% pollen using paint brush (T3). While, minimum pulp weight (92.67 g) was recorded in Self-pollination (T2). This might be due to pollen source affects the growth of ovarian tissues with respect to hormones released by growing endosperm and embryo tissues, which diffuse into the ovarian tissue and exert specific effect on the fruit growth. Earlier similar kind of results has been found by Hansraj Meena (2020) [13], Atawia *et al*. (2016) [2] in citrus, Saleh *et al.* (2014) [26] and Ullah *et al*. (2018) [30] in date palm.

Rind weight (g)

The minimum rind weight (85.33 g) was recorded in hand pollination with 40% pollen + 60% corn starch using sprayer (T10) and it was at par with natural pollination (T1). While, it was noted maximum (165.00 g) in hand pollination with 100% pollen using paint brush (T3). This might be due to larger fruit size and volume due to proper pollination and fertilization might affect the weight of rind. The results are in accordance with the finding Cogez and Lyannaz (1994) [5],

Jalikop and Ravindra Kumar (2007) [15] and Richardson and Anderson (1995) [25] in cherimoya.

Seed weight (g)

Minimum seed weight (22.00 g) was recorded in hand pollination with 40% pollen + 60% corn starch using sprayer (T10). While, maximum seed weight (40.00 g) was noted in hand pollination with 60% pollen + 40% corn starch using sprayer (T9). In conformity with the similar variations observed by Pinto *et al.* (2005), Jalikop and Ravindra Kumar (2007) [15] and Atawia *et al*. (2016) [2] in citrus.

Number of seeds/fruit

Significantly minimum number of seeds per fruit (39.00) was noted in natural pollination (T1) and was at par with hand pollination with 40% pollen + 60% corn starch using sprayer (T10), hand pollination with 100% pollen using paint brush (T3) and Self- pollination (T2). The maximum number of seeds per fruit (55.00) was found in hand pollination with 80% pollen + 20 % corn starch using sprayer (T8). This might be due to ovule development as a fertilization process leads to final seed development. Being an aggregate fruit, multiple ovaries convert into areoles. Each areole contains almost seeds. Number of pollen grains, development of ovule might be a possible reason of seed development. The results are in accordance with the finding Guevara (1992) [12] in apple, Atawia *et al*. (2016) [2] in citrus, Famiani *et al*. (2005) [8], Matsumoto *et al*. (2007) [18] and Razeto *et al*. (2008) [24] in kiwi.

Stone fruit (%)

The minimum stone fruit (1.70%) was recorded in hand pollination with 40% pollen + 60% corn starch using paint brush (T6) and it was at par with hand pollination with 100% pollen using paint brush (T3). Whereas, the maximum stone fruit (9.63) was recorded in natural pollination (T1). There are less stone fruit found in hand pollination compare to natural and self-pollination. Earlier similar kind of results has been found by Hansraj Meena (2020) [13].

Table 2: Effect of different pollination methods on fruiting parameter and yield parameter of custard apple cv. Sindhan

Sr. No.	Treatment details	Pulp weight (g)	Rind weight (g)	Seed weight (g)	No. of seeds	Stone fruit (%)	No. of fruits/ plant	Yield (kg/ plant)	Yield (t/ha)
T1	Natural pollination	97.00	93.00	28.67	39.00	9.63	89.33	23.67	6.29
T2	Self- pollination	92.67	104.00	25.33	42.66	8.13	20.00	4.00	1.06
T3	Hand pollination with 100% pollen using paint brush	191.33	165.00	37.67	42.00	1.73	433.33	86.67	23.05
T4	Hand pollination with 80% pollen + 20% corn starch using paint brush	141.00	158.00	38.67	47.00	3.07	353.33	70.67	18.80
T5	Hand pollination with 60% pollen + 40% corn starch using paint brush	174.00	134.33	37.33	48.00	3.70	311.67	62.33	16.58
T6	Hand pollination with 40% pollen + 60% corn starch using paint brush	118.33	114.33	31.33	54.66	1.70	325.00	65.00	17.29
T7	Hand pollination with 100% pollen using sprayer	179.67	154.66	27.33	45.66	3.10	380.00	76.00	20.21
T8	Hand pollination with 80% pollen + 20% corn starch using sprayer	146.33	150.33	37.00	55.00	5.20	250.00	50.00	13.30
T9	Hand pollination with 60% pollen + 40% corn starch using sprayer	128.33	139.66	40.00	52.66	4.30	258.33	51.62	13.72
T10	Hand pollination with 40% pollen + 60% corn starch using sprayer	105.33	85.33	22.00	41.20	3.37	35.00	47.00	12.50
S.Em.±		2.83	2.69	0.93	1.19	0.08	4.61	1.03	0.27
C.D. at 5%		8.40	8.01	2.76	3.53	0.25	13.70	3.07	0.81
C.V.%		3.56	3.59	4.95	4.40	3.28	3.01	3.33	3.33

No. of fruits/plant

Significantly maximum number of fruits per plant (433.33) was estimated in hand pollination with 100% pollen using paint brush (T3) followed by hand pollination with 100% pollen using sprayer (T7) and lowest (20.00) was in Self-pollination (T2). Total number of fruits per plant was estimated by multiplying number of fruit per shoot in which hand pollination was carried out with total number of shoots per plant. The result showed estimated yield. This might be due to higher number of fruit set as a result of better fertilization with hand pollination using paint brush and sprayer. The result was supported by Campos *et al.* (2004) [4], Pinto *et al.* (2005) [21], Pritchard and Edwards (2006) [22], Melo *et al*. (2004) [19] in atemoya, Saleh *et al.* (2014) [26] in date palm and Gonzalez *et al*. (1998) [11] in kiwi.

Fruit yield (kg/plant)

The highest yield per plant (kg) was recorded (86.67kg) in hand Pollination with 100% pollen using paint brush (T3) followed by hand pollination with 100% pollen using sprayer (T7). minimum (4.00 kg) yield was found in Self- Pollination (T2). This might be due to hand pollination leads to more number of the fruit and also due to fruit setting percentage. Such type of variability was recorded by Vinay *et al*. (2017) [11], Hansraj Meena (2020) [13], Elrefaey and Eldengawy (2014) [6] and Ullah *et al*. (2018) [30] in date palm.

Fruit yield (t/ha)

The maximum fruit yield (23.05) was noted in hand pollination with 100% pollen using paint brush (T3) followed by hand pollination with 100% pollen using sprayer (T7). Minimum (1.06) yield was found in Self- pollination (T2). This might be due to the much variation in the yield per plant due to different pollination methods. The similar variation was also observed by Vinay *et al*. (2017) [11], Hansraj Meena (2020) [13], Elrefaey and Eldengawy (2014) [6] and Ullah *et al*. (2018) [30] in date palm.

Conclusion

Based on field experimentation, it seems quite logical to concluded that there was distinct variations among the different treatments for fruiting, yield and quality parameters. The treatment hand pollination with 100% pollen using paint brush performed better as compared to other treatments in majority of characters. The treatment of hand pollination with 100% pollen using sprayer have also a potentiality to give better yield which was easier and less laborious. The result of present investigation will be helpful for increasing production of custard apple in which there is problem of low fruit set due to protogynous dichogamy. From the above it can be

concluded that hand pollination with 100% pollen using paint brush is an effective approach which helps not only in good fruit set but also produces good quality fruits.

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