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IMPACT OF POLLINATION ON POMEGRANATE

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ABSTRACT

Pollination mode affects crop quality and quantity in several economically significant crops. This study examined the effects of open pollination, *Apis cerana* pollination, hand, hand+ self-pollination, and self-pollination on pomegranate fruits. Open-pollinated plants had higher fruit length, weight, rind thickness, total soluble sugars, reducing sugar content, non-reducing sugar content, and total soluble solids, followed by *A. cerana* pollinated plants. *A. cerana* pollination increased pomegranate output and quality, including fruit shape, aril weight, TSS, and sugar content. The study found that open pollination and *A. cerana* integration increase pomegranate fruit yield and quality. *A. cerana* integration boosts farmers' income and conserves biodiversity.

Key words: Non-reducing sugars, *Apis cerana*, open pollination, reducing sugar, hand pollination, fruit yield, income, biodiversity, self pollination, fruit quality

In the past, our focus was on boosting yield to meet the national demand. Since yield is rising owing to different variables, researchers are also focusing on quality characteristics. Recent research suggest that insect pollination improves quantity and quality (Stein et al., 2017; Veereshkumar et al., 2020; Kumar et al., 2020; 2021). The Punicaceae fruit pomegranate (*Punica granatum* L.) is popular in tropical and subtropical regions. Reports say pomegranates are grown worldwide between 41° N and 42° S (Hodgson 1917). It is grown on 1.20 lakh ha in India and produces 28.45 lakh tons and 6.6 mt/ ha (Kumar et al., 2020). Maharashtra produces the most of this fruit in India. It has become a major Indian export crop in the previous decade (Chandra and Jadhav, 2008). The pomegranate plant is an andromonoecious due to the coexistence of male (unfertile), intermediate, and hermaphrodite (fertile) flowers on the same plant. This facilitates insects in cross-pollination, aiding plants to produce more fruit. Pomegranate plants exhibit both self-pollination and cross-pollination; however, cross-pollination is desired for a higher yield (Jambagi and Nandini, 2022). Hand pollination produced more fruit sets than open conditions in different crops (Josan et al., 1979; Bavale, 1978; Veereshkumar et al., 2017).

Naturally, insects are deemed to be the primary agents responsible for the transfer of pollen. Numerous studies conducted in India, Turkmenistan, and Tunisia have examined the emasculation and pollination of various pomegranate cultivars. These studies have demonstrated that the fruit is naturally produced through self-pollination (Karale et al., 1993; Levin, 1994; Nalawadi et al., 1973). However, the degree of fruit set resulting from self-pollination varies among different pomegranate cultivars (Kumar et al., 2004). The variation in cross-pollination was varying among different cultivars of pomegranate (Aksoy and Dalkilic, 2019).Previous scientific research has shown that self-pollination can also result in significant crop yields (Martinez et al., 2009; Patil and Pastagia, 2016), despite some research suggesting that insect pollinators, such as honey bees, are beneficial in improving pomegranate crop yield and fruit quality (Vazifeshenas et al., 2015). This raises concerns about whether pollinators are necessary for pomegranates or if self-pollination is adequate. However, there is currently very limited knowledge on pomegranate cross-pollination and its impact on pomegranate fruit, especially in Bhagwa variety. The study hypothesizes that integrating honey bees (*A. cerana*) will increase pomegranate fruit quality and quantity. Hence, the current research was conducted to comprehend the impacts of various pollination modes on pomegranate fruit, especially in the eastern dry zones.

MATERIALS AND METHODS

The experiment was carried out in two locations horticulture field, University of Agricultural Sciences, GKVK, Bangalore (13.0767° N, 77.5776° E), Karnataka, and as well as in the farmer's field at

Koramangala, Devanahalli (13.2924° N, 77.7516° E), Bangalore, Karnataka. The experimental area has a yearly rainfall ranging between 670.6 and 888.6 mm, with the kharif season receiving more than half of that total. A standard package of practices was followed in the cultivation and management of the crop. In this study, we used the pomegranate cultivar Bhagwa and five different treatments were evaluated: T_1: pollination by *A. cerana* (where ten pomegranate plants caged with *A. cerana* bee colony with nylon net (1 mm size)); T_2: hand pollination with emasculation; T_3: self-pollination (bagged flowers); T_4: hand + self-pollination and T_5: open pollination (in which all species of pollinators that visit pomegranate blooms normally were permitted to do so). The fruit quantitative parameters viz., fruit diameter (mm), fruit length (cm), fruit weight (g), test weight(g), total seed weight per fruit (g), total no. of seeds per fruit and rind thickness (mm) were recorded using standard procedures. The qualitative parameters viz., refractive index was measured using a hand refractometer. Total soluble sugars (TSS) were quantified by utilizing anthrone reagent, as outlined in the methodology established by Dubios et al. (1951). The degree Brix of total soluble solids in the samples was measured using a digital refractometer (ATAGO RX-5000) at 20°C. Reducing sugars was quantified using the methodology outlined by Ranganna (2001). The methodology proposed by Malhotra and Sarkar (1979) was utilized to determine non-reducing sugar. The ash content was ascertained through the utilization of a muffle furnace (Thiex and Novotny, 2012).

RESULTS AND DISCUSSION

Open-pollinated plants had a much longer fruit length (10.30 cm), followed by *A. cerana* (8.96 cm) and hand-pollination (7.67 cm) (Table 1). Other researchers reported similar results (Karimi and Mirdehghan, 2015; Wetzstein et al., 2011), where higher fruit length was recorded in cross-pollinated pomegranate. Self-pollinated plants had smaller fruits due to poor ovule development, pollination, or fertilization, even within

Table 1. Fruit yield parameters of pomegranate (var. Bhagwa) as influenced by modes of pollination

Treatment	Fruit diameter (mm)	Fruit length (cm)	Fruit Weight (g)	Test weight (g) (100 seeds weight)	Total seed Weight per fruit (g)	Total no. of seeds per fruit	Rind thickness (mm)
Quantitative							
T1	23.50	8.96[b]	228.47[b]	35.47[a]	154.20[a]	405.66[b]	0.13[b]
T2	22.55	7.67[c]	159.53[c]	32.45[b]	92.45[c]	299.00[c]	0.15[b]
T3	21.65	8.30[c]	154.89[c]	27.70[b]	109.30[c]	288.33[c]	0.20[b]
T4	22.47	8.10[d]	178.76[bc]	29.25[b]	115.15[b]	287.00[c]	0.25[b]
T5	24.92	10.30[a]	277.54[a]	28.40[b]	158.47[a]	499.00[a]	0.45[a]
Mean	23.02	8.66	199.84	30.65	125.91	355.79	0.24
CV	4.47	2.20	8.90	11.59	11.78	5.56	5.50
CD (p= 0.05)	NS	0.10	27.41	6.48	18.55	1.60	0.07

Treatments	Total soluble sugars (%)	Reducing sugars (%)	Non reducing sugars (%)	Refractive index of fruit juice	Ash content (%)	Total soluble solids
Qualitative						
T1	44.12[b]	36.91[b]	7.20[a]	1.34[b]	0.59[b]	16.75[a]
T2	33.56[c]	34.05[b]	6.29[a]	1.35[b]	0.54[c]	14.75[b]
T3	31.23[c]	32.40[b]	4.44[b]	1.35[b]	0.67[a]	14.92[b]
T4	36.09[c]	34.90[b]	11.63[a]	1.34[b]	0.57[c]	15.15[a]
T5	55.29[a]	42.23[a]	13.06[a]	1.39[a]	0.58[b]	15.25[a]
Mean	40.05	36.10	5.89	1.35	0.60	15.36
CV	5.76	5.58	3.43	1.43	1.43	3.94
CD @ 5%	3.43	3.13	7.66	0.097	0.097	1.34

T_1: pollination by *A. cerana*; T_2: hand pollination with emasculation; T_3: self-pollination; T_4: hand + self-pollination and T_5: open pollination a genotype (Wetzstein et al., 2011). No statistically significant variations were observed in the fruit diameter across the treatments. The test weight of seeds varied among treatments whereas, *A. cerana* pollinated plants had the highest test weight (35.47g), while self-pollinated plants had the lowest (27.70), which was on par with hand-pollinated plants (32.45g) and hand + self-pollinated plants (29.25). Hand-pollinated plants had the lowest seed weight per fruit (92.45g) while open-pollinated plants had the greatest (158.47g). The significantly highest number of seeds per fruit was recorded in open-pollination (499.00), followed by *A. cerana* pollinated plants (405.66) and least in hand + self-pollinated plants (287.00). Derin and Eti (2001) and Karimi and Mirdehghan (2015) found that cross-pollination produced 100 arils and seeds with greater weights than self-pollination. According to Anonymous (2006), cross-pollination in pomegranate has the potential to enhance fruit quality, specifically in terms of the number of seeds per fruit and fruit size, by up to 68%. Open-pollinated fruit rind thickness was 0.45 mm which was substantially greater. However, the remaining four treatments, hand + self-pollination (0.25 mm), self-pollination (0.20 mm), hand pollination (0.15 mm), and *A. cerana* pollination (0.13 mm) were on par with each other and recorded significantly lower rind thickness compared to open pollination. Supplemental pollination produced the thickest fruit peels of Gorch-e-dadashi and Zaghe-yazdi cultivars, whereas self-pollination produced the thinnest (Karimi and Mirdehghan, 2015). Based on the visual appearance of the fruits, the fine fruit shape was recorded in the *A. cerana* pollinated plants. The number of fruits/plant, percent fruit set, percent malformed fruit, fruit diameter, fruit weight, yield, and yield/ha were highest in open pollination compared to *Apis cerana indica* pollination in bottle gourd (Padhiyar and Patel, 2022).

A. cerana-pollinated plants had the highest TSSs (16.75), followed by open (15.25) and hand + self (15.15) (Table 1). TSS detects soluble solids in a liquid and impacts taste, making it an important produce quality indicator (Hadiwijaya et al., 2020; Bexiga, 2017). Karkar and Ghetiya, (2022) reported that TSS was found to be higher in open-pollinated plants. Significantly highest reducing sugars were recorded in the fruits of open-pollinated plants (42.23%) followed by *A.* cerana pollinated fruits (36.91%), hand + self-pollinated (34.90%), hand-pollinated fruits (34.05%) and self-pollinated (32.24 %). Open-pollinated fruits had 13.06% non-reducing sugars, while hand+ self-pollinated fruits (11.63) and *A. cerana*-pollinated fruits (7.20%) were comparable. Open-pollinated plants had the greatest refractive index of fruit juice (1.39%), whereas the other treatments were comparable. Ash concentration varied significantly across treatments. It increased considerably (0.67%) in self-pollination. The hand + self-pollinated fruit plants (0.57%) and hand-pollinated plants (0.56%) showed significantly lower ash content. Ash % indicates inorganic mineral content (Harris and Marshall, 2017); lower values indicate greater quality. The hand pollination method, which had less ash, had more inorganic minerals. The highest percentages of total soluble sugars were found in open-pollinated fruits (55.29%), *A. cerana* caged plants (44.12%), and hand + self-pollinated plants (36.09%). Both hand-pollinated (33.56%) and self-pollinated (31.23%) plants had the lowest total soluble sugars. Earlier studies had reported that pollination time significantly affects fruit sugars (Kirk and Sawyer, 1997; Moustafa, 1998). Open pollination had superior qualitative and quantitative metrics (Sabbahi et al., 2005; Munawar et al., 2009; Jauker et al., 2012; Hudewenz, 2013). This is due to the fact that in open pollination, plants are permitted to self-pollinate to some extent and pollinator variants such as Apis, Non-Apis, butterflies etc are recorded as afloral visitors (Potts et al., 2010; Kotesh et al., 2023).

In some parameters, *A. cerana* pollination were comparable to open pollination treatments, and 82% of pollination (Fig. 1) was solely due to *A. cerana*, indicating that introducing a colony will increase pollinator density in the field and, indirectly or directly increases pomegranate yield. When caged with *A. cerana*, the fruit's form was observed to be very good, which would increase the product's marketability. Incorporating an *A. cerana* colony will increase pollinator density in the field, thereby increasing pomegranate yield. The *A. cerana* can be used for breeder seed production for

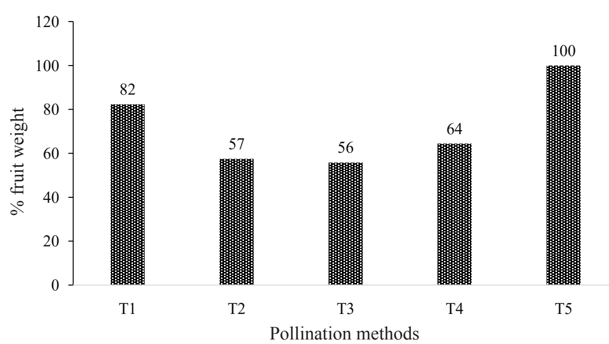

Fig. 1. Fruit weight in comparison with the open pollination (T_1: pollination by *A. cerana*; T_2: hand pollination with emasculation; T_3: self-pollination; T_4: hand + self-pollination and T_5: open pollination)

better yield and quality under closed conditions. Several studies showed that cross-pollination enhances fruit set by 20% and improves quality (Derin and Eti, 2001). Different pomegranate cultivars cross-pollinated in India, Turkmenistan, and Tunisia can enhance fruit set by 67.9%. Self-pollinating "Muscat White" produced 46.0% fruit set (Nath and Randhawa, 1959). Derin and Eti (2001) and Tao et al. (2010) found that bee pollination increases pomegranate fruit set and yield compared to self-pollinated plants. Pomegranate fruit set and weight increased significantly with honey bee pollination (Derin and Eti 2001; Tao et al., 2010).The research affirms that the quantitative parameter was better in open-pollinated plants, followed by *A. cerana* pollinated. While, the *A. cerana* pollinated plants had a beneficial impact on the few qualitative characteristics of pomegranate.

According to earlier research, *Apis cerana* are deserving pollinators for strawberries was reported by Abrol et al. (2017). Installing an *A. cerana* bee colony can potentially increase crop yield and generate additional income for farmers. *A. cerana* is considered a proficient pollinator compared to other species of Apis and non-Apis. The compact size of bee colonies facilitates ease of management for beekeepers, resulting in improved yield. Additionally, their convenient nature and low maintenance requirements make them a practical choice. In general, the presence of these bees has been found to enhance pomegranate yield compared to self-pollination and hand pollination. The maximum pollination efficiency index was recorded for *A. cerana* (Reddy et al., 2022; Kedswin et al., 2023). Therefore, using *A. cerana* for pollinating pomegranate is recommended to achieve higher crop yields. The establishment of a bee colony has the potential to provide farmers with a supplementary source of income.

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AUTHOR STATEMENT CONTRIBUTION

Kotesh Y Chavhan: Conceptualization; Methodology; Investigation; K S Jagadish and Eswarappa G: Conceptulaization and Supervision; D Shishira : Investigation, Data Analysis and Writing the original Draft and Uthappa A R: Data analysis and Writing, reviewing and editing.

CONFLICT OF INTEREST

No conflict of interest.

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