



Differential responses of red pollen parents on colour of green maternal parents of apple (*Malus × domestica*) cultivars

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Apple (*Malus × domestica* Borkh.) is one of the most widely produced and economically important fruits in temperate regions (Velasco *et al.* 2010). Red apple varieties often have better marketability and a higher economic value (Wang *et al.* 2018). Fruit colour development is a major focus of apple breeders and researchers. Fruit colour is mainly determined by anthocyanins (Chen *et al.* 2021). In apples, cyanidin is the main type of anthocyanidin. The name "xenia" was first used to describe the variations in fruit and seeds that result from fertilization by various pollens in terms of size, shape, colour, dimensions, and chemical composition. Additionally, the pollen's metaxenia impact aids in the selection of apple parents to enhance pollination quality (Sharma *et al.* 2024). The research was designed to ascertain the impact of the pollen grain on the general quality mainly the colour of specific apple types while keeping in mind the significance of pollination and pollen influence on the xenia quality. The present experiment was conducted during 2021 at Sher-e-Kashmir University of Agricultural Science and Technology of Kashmir, Shalimar, Srinagar (34° 9'22" N latitude, 74° 52' 55" E longitude; elevation of 1,685 m msl), Jammu and Kashmir to determine the impact of the colour of red-coloured cultivars (Anna, Gala Redlum, Red Velox, Red Chief, Red Chief Camspur, and Red Gold) on the green-coloured maternal cultivars of apples (Golden Delicious Reinders, Golden Clone-B, Granny Smith, Sunhari, Pinova) (Supplementary Table 1). The crossing plan has been described in Supplementary Table 2. The orchard had proper air drainage. The soil was moderately deep, having medium fertility status. The trees were spaced at 3 m × 1 m and received uniform recommended cultural

practices during the studies. A single tree in each cultivar constituted an experimental unit and each cultivar was replicated three times. The plants were regularly weeded. Fertilizers were applied as per schedule. All recommended package of practices for apple cultivation were followed as per schedule. After counting the blossoms, each tree from each cultivar that was marked had three branches on three sides. They were left as such for open pollination. Cross pollination was done in an emasculated flowers dipping a small, soft brush into a glass vial containing the pollen and touching the brush on to the stigma. It can also be done in same way but using fingertip instead of brush for quick and effective pollination. Flowers at popcorn stage that one likely to open next day were selected and emasculated.

Observations were recorded on fruit set (number of flowers pollinated/the number of fruits set×100); fruit drop (number of fruits initially set/number of fruits retained after subtracting fruit retention from initial fruit set×100); fruit retention in percentage (number of fruits that were carried to maturity/number of flower buds selected and bagged for pollination); and fruit colour by hunter colour lab. Twenty days after cross pollination, fruit set on the basis of total number of flowers pollinated under different modes of pollination was recorded. Final fruit set was calculated by counting the number of fruits that were carried to maturity and dividing them by the number of flower buds selected and bagged for pollination.

Statistical analysis: The observations recorded were subjected to statistical analysis as per the method Op-Stat. The significant difference in the means was tested against the critical difference at 5% significance.

Fruit set, fruit retention, and fruit drop: The highest mean initial fruit set (76.33%) was recorded with pollinizer 'Red Gold' followed by 'Golden Delicious Reinders' (75.18%) and the lowest in the initial fruit set was recorded in Anna (51.44%) (Fig. 1 and Table 1). Regarding the interaction between pollen source and maternal parents the highest fruit set was observed in Golden Delicious

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Reinders × Red Gold (84.09%) and a minimum (38.33%) in Pinova × Anna. The highest fruit retention (79.99%) was observed in Golden Clone-B and the lowest (60.13%) in Anna (Fig. 1 and Table 1). Regarding the interaction between pollen source and maternal parents, the highest fruit retention was observed in Golden Delicious Reinders × Red Gold (80.41%) and minimum (48.80%) in Pinova × Anna. The maximum fruit drop under open pollination (39.87%) was noticed in Anna and the minimum (20.01%) was observed in Golden Clone B and Red Gold. In the same trend maximum fruit drop from planned hand pollination (51.20%) was calculated in Pinova × Anna combination and minimum drop (19.59%) was noticed in ‘Golden Delicious Reinders × Red Gol’ (Fig. 1 and Table 1). The differences among examined pollen sources for this characteristic are significant. The difference in fruit set within the same variety using different pollinizers is attributed to the degree of compatibility within combinations, the higher compatibility resulted in higher fruit set (Tatari *et al.* 2017). Besides genetic differences, there could be several reasons for such differences in the initial and final fruit set between the varieties like temperature, weather conditions, effective pollination period of varieties, stigma receptivity, ovule longevity, pollen tube growth, diploid or triploid nature of varieties, post-bloom temperature, stage of hand pollination, the skill of emasculation during hand pollination and fertilization process (Verma *et al.* 1997).

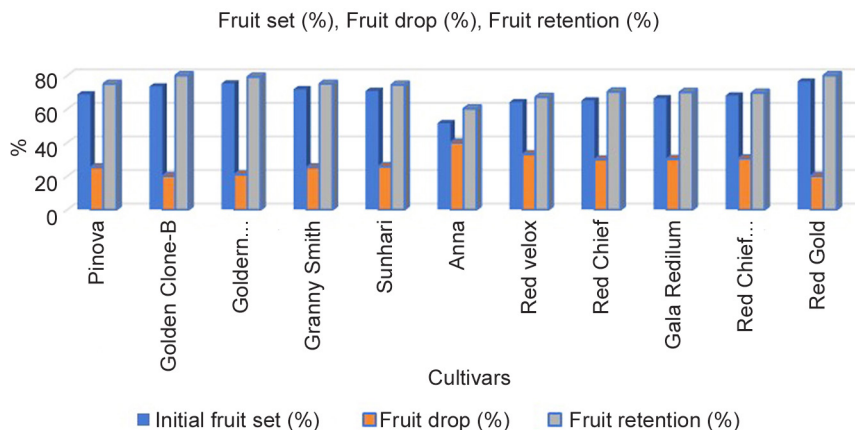


Fig. 1 Initial fruit set, fruit drop, and fruit retention of different apple cultivars under open pollination conditions.

Teskey and Shoemaker (1972) claimed that in apples, fruit containing less than 3 seeds is shed first when the fruit set is abundant. Racsco *et al.* (2007), argued in favour of the effect of preceding temperature as an important factor responsible for the June drop in apples.

Fruit colour: A perusal of the data recorded concerning fruit colour depicted that the value of fruit colour (L* value) was noticed in a cross combination of ‘Golden Clone-B × Red Velox followed by Granny Smith × Red Gold (Table 2 and 3). While a minimum value of ‘L’ was noticed in Pinova × Gala Redlum. The highest value of ‘a’ was noticed in a cross combination of Sunhari × Red Chief followed by Pinova × Red Chief Campsur, and the lowest was found in Granny Smith × Gala Redlum followed by ‘Granny Smith × Red Gold’. Similarly the value of ‘b’ was noticed as highest in a cross combination of ‘Golden Delicious Reinders ×

Table 1 Effect of pollen source on initial fruit set and fruit retention of apple cultivars

| Pollen parent (♂) | Anna (P1) | Red Velox (P2) | Red Chief (P3) | Gala Redlum (P4) | Red Chief Campsur (P5) | Red Gold (P6) | Mean | Anna (P1) | Red Velox (P2) | Red Chief (P3) | Gala Redlum (P4) | Red Chief Campsur (P5) | Red Gold (P6) | Mean |
|--------------------------------|-----------|----------------|----------------|------------------|------------------------|---------------|-------|-----------|----------------|----------------|------------------|------------------------|---------------|-------|
| Maternal parent (♀) | | | | | | | | | | | | | | |
| Pinova (M1) | 38.33 | 64.66 | 65.33 | 70.66 | 65.56 | 77.33 | 63.64 | 48.80 | 70.62 | 74.79 | 79.97 | 76.02 | 80.19 | 71.73 |
| Golden Clone-B (M2) | 45.21 | 71.66 | 73.66 | 76.61 | 70.21 | 80.33 | 69.61 | 54.77 | 71.07 | 75.02 | 79.96 | 75.39 | 79.93 | 72.69 |
| Golden Delicious Reinders (M3) | 43.33 | 69.21 | 71.90 | 77.66 | 68.66 | 84.09 | 69.14 | 55.23 | 69.83 | 74.99 | 80.38 | 74.47 | 80.41 | 72.55 |
| Granny Smith (M4) | 46.34 | 66.66 | 69.21 | 75.88 | 67.66 | 79.91 | 67.61 | 55.74 | 69.13 | 74.74 | 79.24 | 74.68 | 79.94 | 72.25 |
| Sunhari (M5) | 41.66 | 62.88 | 68.56 | 75.65 | 63.62 | 79.80 | 65.36 | 49.99 | 69.99 | 75.06 | 80.00 | 74.76 | 79.95 | 71.63 |
| Mean | 42.97 | 67.01 | 69.73 | 75.29 | 67.14 | 80.29 | | 52.91 | 70.13 | 74.92 | 79.91 | 75.06 | 80.08 | |
| CD ($P \leq 0.05$) | | | | | | | | | | | | | | |
| Maternal parent (M) | | | | 0.02 | | | | | | | 0.60 | | | |
| Pollen parent (P) | | | | 0.02 | | | | | | 0.66 | | | | |
| M × P | | | | 0.05 | | | | | | | 1.48 | | | |

Table 2 Effect of pollen source on fruit drop (%) and fruit colour (L*) of different apple cultivars of different apple cultivars

| Pollen parent (♂) | Anna (P1) | Red Velox (P2) | Red Chief (P3) | Gala Redlum (P4) | Red Chief Camspur (P5) | Red Gold (P6) | Mean | Anna (P1) | Red Velox (P2) | Red Chief (P3) | Gala Redlum (P4) | Red Chief Camspur (P5) | Red Gold (P6) | Mean |
|--------------------------------|-----------|----------------|----------------|------------------|------------------------|---------------|-------|-----------|----------------|----------------|------------------|------------------------|---------------|-------|
| Maternal parent (♀) | | | | | | | | | | | | | | |
| Pinova (M1) | 51.20 | 29.38 | 25.21 | 20.03 | 23.98 | 19.81 | 28.27 | 44.77 | 43.49 | 44.74 | 43.06 | 43.83 | 43.50 | 43.89 |
| Golden Clone-B (M2) | 45.23 | 28.93 | 24.98 | 20.04 | 24.61 | 20.07 | 27.31 | 52.22 | 59.93 | 57.84 | 55.77 | 54.87 | 56.53 | 56.19 |
| Golden Delicious Reinders (M3) | 44.77 | 30.17 | 25.01 | 19.62 | 25.53 | 19.59 | 27.45 | 51.71 | 52.68 | 53.93 | 49.75 | 51.75 | 51.54 | 51.89 |
| Granny Smith (M4) | 44.26 | 30.87 | 25.26 | 20.76 | 25.32 | 20.06 | 27.76 | 57.86 | 57.21 | 56.30 | 55.67 | 57.90 | 58.73 | 57.27 |
| Sunhari (M5) | 50.01 | 30.01 | 24.94 | 20.00 | 25.24 | 20.05 | 28.38 | 52.90 | 53.42 | 52.37 | 52.70 | 51.71 | 53.14 | 52.70 |
| Mean | 47.09 | 29.87 | 25.08 | 20.09 | 24.94 | 19.92 | | 51.89 | 53.34 | 53.03 | 51.39 | 52.01 | 52.68 | |
| CD ($P \leq 0.05$) | | | | | | | | | | | | | | |
| Maternal parent (M) | | | | 0.06 | | | | | | | 1.05 | | | |
| Pollen parent (P) | | | | 0.07 | | | | | | | 1.15 | | | |
| M × P | | | | 0.14 | | | | | | | 2.57 | | | |

Red Gold' followed by 'Golden Delicious Reinders × Red Chief' and lowest in Pinova × Anna highest in Granny Smith followed by Golden Clone-B, whereas 'a*' value of fruit color was recorded as negative in green varieties and positive in red varieties of the fruit samples (Table 3 and Supplementary Table 3). The highest value of 'a' was noticed in Red Velox followed by Gala Redlum while the lowest value of 'a' was noticed in Granny Smith followed by Golden Delicious Reinders. Similarly value of 'b' was noticed as highest in Granny Smith and lowest in Red Gold. A perusal of the data recorded concerning fruit colour under hand pollination of apple cultivars. This result was supported by the finding of Drake and Eisele (2007).

Table 3 Fruit colour (L*, a*, b*) of different apple cultivars under open pollination

| Cultivars | L* | a* | b* |
|---------------------------|-------|--------|-------|
| Pinova | 53.28 | -10.71 | 34.25 |
| Golden Clone-B | 65.64 | -14.66 | 45.57 |
| Golden Delicious Reinders | 64.98 | -15.91 | 48.18 |
| Granny Smith | 69.61 | -19.30 | 48.94 |
| Sunhari | 63.79 | -12.29 | 46.70 |
| Anna | 43.84 | 25.80 | 37.15 |
| Red velox | 47.62 | 39.11 | 18.99 |
| Red Chief | 41.76 | 36.92 | 17.28 |
| Gala Redlum | 38.87 | 38.29 | 19.37 |
| Red Chief Camspur | 43.16 | 34.79 | 18.39 |
| Red Gold | 45.68 | 32.49 | 12.91 |
| Mean | 52.20 | 13.41 | 30.25 |
| CD ($P \leq 0.05$) | 5.11 | 3.23 | 0.69 |

SUMMARY

Under open pollination conditions, the highest fruit set was observed in Red Gold (76.33%) and the lowest in Anna (51.44%). Cross-compatibility studies revealed that Red Gold as pollinizer gave the highest fruit set in Golden Delicious Reinders (84.09%), whereas Anna showed partial compatibility with Pinova (38.33%), Sunhari (41.66%) and Golden Delicious Reinders (43.33%). Anna used as male against female parents registered maximum fruit drop in Pinova (51.20%). The source of pollen also had positive and significant effects on the fruit's qualitative characteristics i.e. colour. From the present study, it is concluded that the varieties Red Gold and Gala Redlum were the best pollen sources and exhibited maximum compatibility with most of the varieties.

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