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Influence of pollen sources on quality characteristics of exotic apple (*Malus x domestica*) cultivars in North Indian Himalayas

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Abstract

The present investigation was conducted at a demonstration farm of Krishi Vigyan Kendra Shopian. The study reveals two years data (2021 & 2022) under open pollination and planned hand pollination to increase the quality and productivity of apple. There are issues in proper pollination due to non availability of proper pollinizer plant ratio in the orchards and lack of pollinators as well in Kashmir valley. The experiment was conducted on eleven apple varieties to carry out the trial on open pollination and planned hand pollination to see the pollen compatibility and effects of pollen source on fruit quality. Under open pollination conditions, the maximum average fruit weight (161.06 and 163.34g) was observed in Oregon spur and the minimum average fruit of 120.01 and 123.55g weight recorded in Royal Gala during the years of study. Under planned hand pollination, the maximum fruit weight of 150.31 and 152.57g was noticed in 'Gala Must x Red Gold'. The minimum fruit weight of 123.50 and 121.43g observed in 'Gala Must x Early Red One' cross combination. Under open pollination, the maximum average fruit length of 9.20 and 9.38cm has been observed in Oregon spur and the least length of fruits (5.42 and 5.73 cm) noticed in the Braeburn cultivar. Under planned cross pollination, the maximum fruit length of 8.78 and 9.27cm was observed in 'Gala Must x Golden Delicious' and a minimum fruit length of 6.57 and 6.76cm was noticed in cross combination 'Gala Must x Red Gravenstein. Under open pollination, Gala Must recorded a maximum average fruit diameter of 9.73 and 9.93cm, and a minimum fruit diameter of 6.63 and 6.85cm was noticed in Braeburn cultivar. Under planned hand pollination, the maximum diameter of fruits (9.68 and 9.91cm) recorded in 'Gala Must x Golden Delicious' and minimum diameter of fruits (7.38 and 7.85cm) was noticed in 'Gala Must x Red Gravenstein' combinations, during both the years 2021 and 2022, respectively. The results of the study shows that pollinizer varieties Gala Must, Oregon Spur, Golden Delicious and Red Gold, when used as pollen donors have positively influenced the quality of apple under the desired pollination plan.

Keywords: Apple, pollination, fruit quality, pollen source

Introduction

The area under apple cultivation in Jammu and Kashmir state is 171.610 thousand ha with the production of 2146347.04 thousand MT and productivity 12.50 MT/ha^[1]. However, the productivity of Jammu and Kashmir is very low as compared to the productivity of horticulture advanced countries like Chile (47.22 MT/ha) and Netherlands (44.97 MT/ha). The main reason for low productivity is improper plantation practices in orchards, lack of knowledge about proper pollination. Influence of pollen on quality attributes of apple for attainment of better dividends. The purpose of this study was to identify the pollinizer varieties and appropriate method of pollination among apple cultivars to enhance the production level and quality to a considerable extent for the best interest of fruit industry. Most apple cultivars do not produce fruits by self-pollination or by crosses between genotypes that have the same alleles in the *S*-locus, responsible for gametophytic self-incompatibility control^[2-3]. Pollinizers must coincide at flowering time with the scion cultivars^[4-5]. In addition, scion cultivars and pollinizers need to be genetically compatible^[6]. Since the pollen tube does not grow when the *S*-allele in the haploid cell of the pollen grain is the same to one of the two *S*-alleles expressed in the pistil^[7-8]. The gametophytic self-incompatibility is a barrier to identify and use compatible plants for direct cross pollination in the field that enables fruit set^[9]. Likewise, fruit growers cannot produce fruit optimally when incompatible genotypes are grown in the orchards^[10].

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In order to ensure the formation of symmetrical fruit with normal shape development, at least one seed must be formed in four of the five fruit carpels^[11-12]. The normal apple shape formation is induced through hormones released by the developing embryos, so the ovule fertilization and the consequent seed formation in the carpels are necessary to obtain fruit with appropriate shape^[13]. Over 7,500 apple cultivars are known and used not only for fresh consumption but also for consumption as processed products like juice, pie, or cider^[14]. These products have beneficial effects on Alzheimer's disease, bone health, cognitive decline during normal aging, diabetes, and gastrointestinal protection from drug injury^[15]. Apple is the most produced fruit in temperate climates and is expanding into subtropical and tropical areas^[16]. However, recent global climate changes manifested in rising temperatures and late frosts in the flowering season caused poorer coloring of apple fruit skin and frost damage to pistils^[17]. The central flowers had an intense but short stigmatic activity, whereas lateral flowers had a discrete but much longer stigmatic activity^[18]. As apple (*Malus x domestica*) shows gametophytic self and cross-incompatibility, and at least two genetically, distinct cultivars are necessary for stable apple production. Therefore, pollination is an important and inseparable component in respect of regular and consistent quality production. In a fruit crop like apple, pollination is of utmost significance and its proportion and magnitude is primarily based upon appropriate selection of varieties^[19]. The viability, pollen tube growth and morphological homogeneity related to pollen quality are the most important properties in fruit trees. These properties are useful for plant breeders, geneticists, researchers, development departments and growers^[20]. Therefore, the study was made to identify the varieties which bloom together or in sequence and the compatibility of these varieties for best possible combinations to improve the fruit set and quality production to the desired level.

Material and Methods

The experimental trial was conducted at a demonstration farm of Krishi Vigyan Kendra Shopian, during 2021 and 2022. The orchard had proper air drainage situated at an altitude of 1700m above msl. The soil was moderately deep, having a medium fertility status. The soil texture of the experimental farm was sandy loam with soil pH 6.9, average organic matter, phosphorus 0.14 percent, nitrogen 2.10 percent and potassium 1.48 percent. The trees were spaced at 2m x 3m distance on MM106 rootstock and regularly weeded. Manures, fertilizers and other recommendations for apple cultivation were followed as per package of practices for apple crop. The experiment was laid in randomized block design with eleven treatments and three replications. Eleven genotypes of apple uniform in age were taken for experimentation. Single tree in each variety constituted an experimental unit and each cultivar was replicated three times. The eleven genotypes used were Gala Must, Royal Gala, Early Red One, Law Red Rome, Scarlet Spur, Oregon Spur, Braeburn, Ginger Gold, Red Gravenstein', Golden Delicious and Red Gold. For planned hand pollination, three branches on three sides of every tagged tree of each cultivar have healthy flowers were tagged after counting the flowers. The emasculated flowers were cross pollinated by dipping a small, soft camel brush into a glass vial containing the pollen and dusting on to the stigma. Flowers at popcorn stage likely

to open next day were selected and emasculation done. Open flowers as well as late buds removed. The emasculated flowers are covered with bags and then pollinated manually with a camel brush, 24 hours after emasculation with the pollen of the parents as per crossing plan. The flowers labeled after pollination and again covered with muslin bags then removed bags after 20 days of pollination. All possible cross combinations made without reciprocals in diallele crossing design. Under planned hand pollination biometrical method of quantitative genetics in diallele crossing adopted for analysis. The data set was analyzed using diallele method (Griffing's approach model 4) as followed by Singh and Chaudhary^[21]. Data collected was subjected to statistical analysis using statistical software STATISTICA-AG (from stat soft USA) licensed to SKUAST-Kashmir. For quality characteristics, Random composite representative samples from tagged trees of each cultivar had taken at harvesting stage. These samples collected in labeled polythene bags and carried to the laboratory for further investigation. For calculating fruit weight, the random samples collected from each experimental unit of each cultivar weighed on a top pan electronic balance, averaged and recorded. Fruit size was determined by calculating fruit length and diameter from respective samples. The random samples from each experimental unit of each cultivar measured separately with the help of Digital Vernier Caliper in millimeters (mm) and then converted into centimeters (cm). The fruit length averaged and analyzed statistically. For fruit diameter, the random samples from each experimental unit of each cultivar measured separately with the help of Digital Vernier Caliper in millimeters (mm) and then converted into centimeters (cm). The average fruit diameter was determined by dividing the total diameter obtained (cm) by the number of fruits in the sample. The observations recorded were subjected to statistical analysis as per the method of Analysis of Variance^[22]. The significance and non-significance of the treatment effects judged with the help of "F" variance ratio test against the critical difference at 5% level.

Results and Discussion

A. Fruit weight (g) of exotic apple cultivars under open pollination

The data pertaining to fruit weight, given in Table-1, reveals a significant difference in the average fruit weight of apple cultivars under study with the exception of a few varieties, which had noticed a non-significant difference with each other. The maximum average fruit weight (161.06 and 163.34g) was recorded in Oregon, followed by Golden Delicious (157.03 and 158.49g). However, the minimum average fruit weight of 120.01 and 123.55g was recorded in the Royal Gala, followed by 125.13 and 127.72g in Ginger Gold during the years of study 2021 and 2022, respectively. The pooled data revealed that cultivars Red Gold and Golden Delicious, Ginger Gold and Braeburn, Law Red Rome and Gala Must were statistically at par when their average fruit weight was compared with each other.

B. Fruit weight (g) of exotic apple cultivars under planned hand pollination

Perusal of the data depicted in Table-2 depicts significant differences in fruit weight when varieties compared with each other. The weight of hand-pollinated fruits varied from 111.35 to 152.57g during the course of study. Gala Must, as a female

parent, cross pollinated with other varieties, has shown remarkable differences in terms of fruit weight. The maximum fruit weight of 150.31 and 152.57g was noticed in 'Gala Must x Red Gold' followed by 148.51 and 151.55g in 'Gala Must x Law Red Rome' cross combinations in the years of study, respectively. The minimum fruit weight of 123.50 and 121.43g was observed in 'Gala Must x Early Red One' followed by 126.48 and 129.37g in 'Gala Must x Oregon spur' cross combinations during the 2021 and 2022 years, respectively. The other cross combinations with Gala Must also exhibit significant differences from each other. However, the cross combinations 'Gala Must x Law Red Rome' was at par with 'Gala Must x Golden Delicious'. When Royal Gala was used as a female parent, the maximum fruit weight of 145.41 and 143.42g recorded with 'Royal Gala x Red Gold' followed by 142.33 and 135.33g with 'Royal Gala x Golden Delicious' cross combinations, during the course of study. The minimum fruit weight of 111.35 and 113.45g recorded in the cross combination 'Royal Gala x Red Gravenstein' followed by 117.38 and 115.26g with 'Royal Gala x Ginger Gold' cross combination. Significant differences were observed in rest of cross combinations of Royal Gala as female parent. Similarly, Early Red One, Law Red Rome, Scarlet spur, Oregon spur, Braeburn, Ginger Gold, Red Gravenstein and Golden Delicious as a female parents had responded a remarkable influence of different sources of pollen on fruit weight and the results as described in table 2. The pooled data reflected the overall highest fruit weight (151.44g) in 'Gala Must x Red Gold' combination and minimum fruit weight (112.40g) observed in 'Royal Gala x Red Gravenstein' combination. There were significant differences among the various crosses made as per the crossing plan

C. Fruit length (cm) of exotic apple cultivars under open pollination conditions

The data pertaining to the length of open pollinated fruits of various exotic cultivars (Table-3), reveals that average length of fruits varied from 5.42 to 9.20 cm and 5.73 to 9.38 cm during the years of study 2021 and 2022. Among the cultivars under study, the maximum average fruit length of 9.20 and 9.38 cm observed in Oregon spur followed by 9.20 and 9.32 cm in Golden Delicious during the 2021 and 2022, respectively. However, the least length of fruits (5.42 and 5.73 cm) noticed in the Braeburn cultivar, followed by Ginger Gold (6.35 and 6.66cm) during the years of study. The pooled data indicates that Gala Must and Red Gold, Law Red Rome and Scarlet spur, and Early Red One and Royal Gala were statistically at par with each other with respect to the length of fruits.

D. Fruit length (cm) of exotic apple cultivars under planned hand pollination

Perusal of the data with respect to the length of fruits under hand pollination is given in Table-4, it reveals that the length of fruits varied from 6.05 to 9.34cm in 55 cross combinations made between the eleven cultivars. There was a remarkable difference in the fruit lengths of these varieties developed under planned hand pollination. When Gala Must used as a female parent and other varieties as male parents individually, the maximum fruit length of 8.78 and 9.27cm was observed in 'Gala Must x Golden Delicious' followed by 8.76 and 9.15cm in 'Gala Must x Red Gold' and minimum fruit length of 6.57

and 6.76cm was noticed in cross combination 'Gala Must x Red Gravenstein' during 2021 and 2022 years, respectively. The other cross combinations also recorded significant differences from each other. When Royal Gala was used as a female parent, the highest fruit length of 7.89 and 8.34 cm observed in cross combination 'Royal Gala x Red Gold' followed by 7.84 and 8.18 cm in 'Royal Gala x Golden Delicious'. The minimum fruit length of 6.37 and 6.53cm was recorded in 'Royal Gala x Red Gravenstein', which is at par with 'Royal Gala x Ginger Gold' during the study period. Similarly, when the Early Red One variety is used as female parent with other varieties as male parents, the maximum length of fruits (7.98 and 8.38cm) was observed in 'Early Red One x Braeburn', which was statistically at par with 'Early Red One x Red Gold' (7.95 and 8.35cm) followed by a cross combination 'Early Red One x Golden Delicious' (7.85 and 8.25cm) during the course of investigation. The minimum length of fruits (6.35cm and 6.46cm) was noticed in 'Early Red One x Red Gravenstein' followed by 'Early Red One x Ginger Gold' (6.47 and 7.64cm) during the investigation period. When Law Red Rome was used as a female parent with others, the maximum length of fruits (7.77 and 8.56cm) was recorded with cross combination 'Law Red Rome x Red Gold' followed by 'Law Red Rome x Golden Delicious' 7.64 and 8.48 cm however, minimum length of fruits (6.74 and 7.24cm) was noticed in 'Law Red Rome x Red Gravenstein' during the years of study. The results of the rest of cross combinations involving Scarlet spur, Oregon spur, Braeburn, Ginger Gold, Red Gravenstein and Golden Delicious as female parents were in line with the results as described in earlier cross combinations in detail. The pooled data reflected the overall highest fruit length of 9.27cm in 'Oregon spur x Red Gold' combination and minimum fruit length of 6.13cm observed in 'Braeburn x Red Gravenstein' combination. There were significant differences recorded among the various crosses.

E. Fruit diameter (cm) under open pollination

Table-5 represents the observations related to the diameter of open pollinated fruits of apple cultivars. It is evident from the data that fruit diameter varied from 6.63 to 9.73 cm and 6.85 to 9.93 cm during both the years of study. Gala Must recorded a maximum average fruit diameter of 9.73 and 9.93 cm followed by 9.66 and 9.83cm in the cultivar Oregon spur however, the minimum fruit diameter of 6.63 and 6.85 cm noticed in Braeburn cultivar. The pooled data reflected that one set of varieties i.e. Gala Must, Royal Gala, Scarlet spur, Oregon spur, Golden Delicious and Red Gold had significant differences with other set of varieties i.e. Early Red One, Law Red Rome, Braeburn, Ginger Gold and Red Gravenstein.

F. Fruit diameter (cm) under planned hand pollination

Perusal of the data inscribed in Table-6 reveals that the diameter of the fruits varied from 6.82 to 9.91cm among the varieties under study. When Gala Must use as a female parent, the maximum diameter of fruits (9.68 and 9.91cm) recorded in 'Gala Must x Golden Delicious' which is statistically at par with 'Gala Must x Red Gold' (9.62 and 9.81cm) followed by 'Gala Must x Braeburn' (8.95cm and 9.25cm). The minimum diameter of fruits (7.38 and 7.85cm) noticed in 'Gala Must x Red Gravenstein' followed by 'Gala Must x Early Red One' (7.76 and 8.16cm), during the investigation period. When Royal Gala used as a female parent, the highest fruit diameter

of 8.95 and 9.19cm observed in 'Royal Gala x Golden Delicious' which is statistically at par with 'Royal Gala x Red Gold' (8.87 and 9.18cm). The minimum diameter of fruits (7.41 and 7.96cm) found in 'Royal Gala x Red Gravenstein' during studies. Similarly, Early Red One used as a female parent wherein the maximum diameter of fruits (8.43 and 8.84cm) recorded in 'Early Red One x Braeburn' followed by 'Early Red One x Red Gold' (8.36 and 8.68cm) and the minimum diameter of fruits (7.14 and 7.31cm) was observed in 'Early Red One x Red Gravenstein' during the investigation period 2021 and 2022, respectively. In the same way, when Law Red Rome was pollen recipient with others as pollen donors, the fruits so developed with cross combinations had remarkable differences in the diameter. The maximum fruit diameter of 8.45 and 8.64cm observed in 'Law Red Rome x Red Gold' followed by 'Law Red Rome x Golden Delicious' (8.14 and 8.52cm) and the minimum fruit diameter (6.82 and 7.17cm) recorded in 'Law Red Rome x Red Gravenstein'. A similar trend was observed when Scarlet spur used as a pollen recipient in the crossing plan, the maximum fruit diameter of 9.32 and 9.45cm observed in cross combination 'Scarlet spur x Red Gold' followed by 9.11 and 9.31cm in 'Scarlet spur x Ginger Gold'. The 'Scarlet spur x Red Gravenstein' noticed a minimum fruit diameter of 7.45 and 7.67cm during the years of study. Oregon spur as a female parent had shown the highest diameter of fruits 9.62 and 9.78cm in 'Oregon spur x Red Gold' followed by 9.16cm and 9.36cm in 'Oregon spur x Golden Delicious'. The cross combination 'Oregon spur x Red Gravenstein' recorded a minimum diameter of fruits (7.26 and 7.49cm). The results of rest of cross combinations like Braeburn, Ginger Gold, Red Gravenstein and Golden Delicious when used as female parents as per the crossing plan were in tune with the results described in above cross combinations in detail. The pooled data reflected the overall maximum fruit diameter of 9.79cm in 'Gala Must x Golden Delicious' combination and minimum fruit diameter of 6.99cm observed in 'Law Red Rome x Red Gravenstein' combination. There were significant differences among the various crosses made as per the crossing plan.

G. Fruit length diameter ratio under open pollination

The data given in table 7 reveals the maximum length/diameter ratio (0.96 and 0.98) of fruits in the cultivar Red Gold followed by Golden Delicious (0.96 and 0.97) and a minimum length/diameter ratio (0.79 and 0.82) of fruits in the Braeburn and Scarlet spur during the years of study 2021 and 2022. The length/diameter ratio varied from 0.79 to 0.97, however there was a non-significant difference between the varieties under study during the 2022 year. The pooled data depicted the similar trend of non-significant difference between the varieties.

H. Length diameter ratio under planned hand pollination

The data captioned in tables shows that when Gala Must variety is used as a pollen recipient and cross-pollinated with other varieties, the highest fruit length/diameter ratio of 0.94 observed by Early Red One followed by 0.93 in Golden Delicious and Red Gold. The minimum length/diameter ratio of fruits (0.87) recorded with each Oregon spur and Ginger Gold. When Royal Gala is used as a female parent, the other varieties as pollen donors individually, the highest fruit length/diameter ratio of 0.90 and 0.90 observed in 'Royal Gala x Early Red One' and 'Royal Gala x Red Gold'. The

minimum length/diameter ratio of fruits (0.82 and 0.80) found in 'Royal Gala x Ginger Gold' followed by 'Royal Gala x Red Gravenstein' (0.85 and 0.82) during the course of study. Similarly, when Early Red One was used as a female parent and the rest of the varieties as male parents, the maximum length/diameter ratio of 0.96 and 0.96 were recorded in the 'Early Red One x Oregon spur' and 'Early Red One x Red Gold' and 'Early Red One x Golden Delicious'. The minimum length/diameter ratio of fruits (0.81 and 0.87cm) observed in 'Early Red One x Ginger Gold' and 'Early Red One x Scarlet spur' during the years of study. In the same way, when Law Red Rome was used as pollen recipient with other varieties as pollen donors the fruits, so developed with cross combinations had remarkable differences in length/diameter ratios. The maximum fruit length/diameter ratio of 0.99 and 1.00 observed in 'Law Red Rome x Scarlet spur' and each of the crosses combination 'Law Red Rome x Ginger Gold' and Law Red Rome x Red Gravenstein' followed by 0.98 and 0.99 in 'Law Red Rome x Red Gravenstein' and each of the crosses is 'Law Red Rome x Braeburn', 'Law Red Rome x Red Gold' and 'Law Red Rome x Golden Delicious' and the minimum fruit length/diameter ratio of 0.91 and 0.94 recorded in 'Law Red Rome x Red Gold' and 'Law Red Rome x Oregon spur' in the investigation. Similarly, when Scarlet spur was used as a pollen recipient and other cultivars as pollen donors in the crossing plan, the maximum fruit length/diameter ratio (0.89 and 0.93) observed in cross combination 'Scarlet spur x Ginger Gold' and 'Scarlet spur x Braeburn' followed by 0.88 and 0.92 with both crosses 'Scarlet spur x Oregon spur' and 'Scarlet spur x Red Gold' however, minimum fruit length/diameter ratio of 0.84 and 0.85 noticed in 'Scarlet spur x Golden Delicious' during the years of study respectively. When Oregon spur was used as a female parent with other cultivars as male parents individually, the highest length/diameter ratio of 1.02 and 1.01 noticed in cross combination 'Oregon spur x Red Gravenstein' followed by 0.99 and 1.00 in 'Oregon spur x Ginger Gold'. However, the minimum length/diameter ratio of 0.91 and 0.89 recorded in the 'Oregon spur x Braeburn'. The results of the rest of cross combinations like Braeburn, Ginger Gold, Red Gravenstein' and Golden Delicious when used as female parents as per the crossing plan were in consonance with the results described in the above cross combinations in detail. The pooled data reflected the overall maximum fruit length/diameter ratio of 1.01 in 'Oregon spur x Red Gravenstein' combination and minimum fruit length/diameter ratio of 0.81 observed in 'Royal Gala x Ginger Gold' combination. There were significant differences recorded among the various crosses made as per the crossing plan.

Discussion

Quality Attributes of Fruits

It is evident from the data that under open pollination conditions the maximum fruit weight (162.20g) was noticed in Oregon spur and minimum (121.78g) in Royal Gala cultivar during the study period. Similarly, under planned hand pollination the maximum fruit weight (151.44g) was noticed in 'Gala Must x Red Gold' and minimum (112.40g) in 'Royal Gala x Red Gravenstein' combinations during both years of study. Under open pollination, Gala Must recorded a maximum average fruit diameter of 9.73 and 9.93cm and a minimum fruit diameter of 6.63 and 6.85 cm noticed in

Braeburn cultivar during the investigation, period. In the same way, under planned hand pollination, the maximum fruit length of 8.78 and 9.27cm was observed in ‘Gala Must x Golden Delicious’ and a minimum of 6.57 and 6.76cm was noticed in cross combination ‘Gala Must x Red Gravenstein’ during 2021 and 2022, respectively. Under open pollination, Gala Must recorded a maximum average fruit diameter of 9.73 and 9.93cm, however, the minimum fruit diameter of 6.63 and 6.85cm was noticed in Braeburn cultivar during the course of investigation. Under planned hand pollination, the maximum diameter of fruits (9.68 and 9.91cm) recorded in ‘Gala Must x Golden Delicious’ and minimum diameter of fruits (7.38 and 7.85cm) was noticed in ‘Gala Must x Red Gravenstein’ combinations, during the course of investigation. Under open pollination, the maximum fruit length diameter ratio (0.97) was recorded in Red Gold and minimum (0.84) in Braeburn cultivar. Similarly, under planned cross combinations maximum length diameter ratio (1.01) was observed in ‘Oregon spur x Red Gravenstein’ and minimum (0.81) in ‘Royal Gala x Ginger Gold’ combinations. The results obtained may be due to varietal characters and presence of seeds in the fertilized fruits as the fruits containing seeds with endosperm are the sites of gibberellic acid synthesis, where growth substances are produced. As the endosperm is formed the fruit starts growing rapidly under the effect of auxin. Auxin not only helps in utilization of organic substances but influences also the distribution of cytokinins flowing to the fruit, an active sink of metabolites by which fruit weight and size gets increased to a considerable extent. These findings are in consonance with the findings of [23] who observed marked differences in the physical quality parameters of cultivars due to varietal characteristics. [24] reported that the number and distribution of seeds within a developing apple affects its shape and weight. Similar field pollination tests are highly influenced by environmental

conditions and cultural management adopted in the orchards. The number of fruits produced, weight of fruits and number of seeds formed may be different from one year to the next [25]. According to [26], it is necessary that 15-20% of fruit set be observed to ensure adequate levels of commercial production in apple orchards, indicating that all the pollinizer plants tested presented satisfactory effect for fruit set. As the number of seeds formed between the crosses was satisfactory, this suggests good compatibility between pollen and stigma among all the pollinizers tested [27]. However, varieties were identified compatible and semi-compatible crosses among the evaluated pollinizers based on the genotype of the *S*-alleles. According [28], the pollen parent had a varied effect on fruit shape and the effect on inner structure of the fruit was considerable [29] observed that the type of pollinizer used affects fruit shape. Number of seed per fruit is responsible for quality and size of fruits [30-31]. Under ideal conditions, compatible plants may have all seeds formed (normally around ten in *Malus* spp.) while incompatible plants do not grow any seeds (if these plants do not have parthenocarp, they will not form fruits either) [32]. The present study is also in consonance with the earlier reports [33] that sources of pollen have an effect on seed numbers as well as the size and quality of fruit, including their firmness. The higher the seed count, higher the sink strength in the fruits, which is reflected by an increase in fruit weight. Therefore, seeds are important for fruit set and difference in fruit size [34]. A large amount of pollen available can compensate the semi-compatibility between the genotypes, which may explain why it is indistinguishable based on the number of seeds [35]. The production of fruit with good commercial value can be achieved when there is a high density of pollinizer plants in the orchards (translating into high pollen density), even in cases of semi-compatibility.

Table 1: Fruit weight (g) of exotic apple cultivars under open pollination

Genotypes	2021 year	2022 year	Pooled
Gala Must	142.78	145.68	144.23
Royal Gala	120.01	123.55	121.78
Early Red One	156.07	158.58	157.32
Law Red Rome	143.95	146.78	145.36
Scarlet spur	138.67	140.36	139.51
Oregon spur	161.06	163.34	162.2
Braeburn	126.23	128.57	127.4
Ginger Gold	125.13	127.72	126.42
Red Gravenstein	144.68	146.62	145.65
Golden Delicious	157.03	158.49	157.76
Red Gold	156.44	158.43	157.43
CD (5%)	6.53	6.3	4.39

Table 2: Fruit weight (g) of exotic apple cultivars under hand pollination

Genotypes	2021 year	2022 year	Pooled	Genotypes	2021 year	2022 year	Pooled	Genotypes	2021 year	2022 year	Pooled
Gala Must female parent				Royal Gala female parent				Early Red One female parent			
Gala Must x Royal Gala	129.34	135.46	132.4	Royal Gala x Early Red One	131.49	129.43	130.46	Early Red One x Law Red Rome	131.46	133.27	132.36
Gala Must x Early Red One	123.5	121.43	122.46	Royal Gala x Law Red Rome	121.26	122.61	121.93	Early Red One x Scarlet spur	127.52	126.28	126.9
Gala Must x Law Red Rome	148.51	151.55	150.03	Royal Gala x Scarlet spur	125.42	127.31	126.36	Early Red One x Oregon spur	129.45	130.37	129.91
Gala Must x Scarlet spur	139.63	128.42	134.02	Royal Gala x Oregon spur	128.42	131.47	129.94	Early Red One x Braeburn	143.52	141.29	142.4
Gala Must x Oregon spur	126.48	129.37	127.92	Royal Gala x Braeburn	143.29	139.4	141.34	Early Red One x Ginger Gold	137.43	136.24	136.83
Gala Must x Braeburn	144.34	142.63	143.34	Royal Gala x Ginger Gold	117.38	115.26	116.32	Early Red One x Red Gravenstein	123.42	124.35	123.88
Gala Must x Ginger Gold	137.5	139.33	138.41	Royal Gala x Red Gravenstein	111.35	113.45	112.4	Early Red One x Golden Delicious	140.68	139.31	139.99
Gala Must x Red Gravenstein	115.51	118.59	117.05	Royal Gala x Golden Delicious	142.33	135.33	138.83	Early Red One x Red Gold	141.54	143.37	142.45
Gala Must x Golden Delicious	148.41	149.54	148.97	Royal Gala x Red Gold	145.41	143.42	144.41				
Gala Must x Red Gold	150.31	152.57	151.44								
Law Red Rome female parent				Scarlet Spur female parent				Oregon spur female parent			
Law Red Rome x Scarlet spur	131.46	132.38	131.92	Scarlet Spur x Oregon spur	130.71	128.34	129.52	Oregon Spur x Braeburn	137.46	144.37	140.91

Law Red Rome x Oregon spur	133.3	137.56	135.43	Scarlet Spur x Braeburn	138.18	136.66	137.42	Oregon Spur x Ginger Gold	133.34	135.6	134.47
Law Red Rome x Braeburn	139.42	143.34	141.38	Scarlet Spur x Ginger Gold	142.47	135.5	138.98	Oregon Spur x Red Gravenstein	130.62	132.55	131.58
Law Red Rome x Ginger Gold	137.57	142.3	139.93	Scarlet Spur x Red Gravenstein	123.4	121.41	122.4	Oregon Spur x Golden Delicious	143.56	149.41	146.48
Law Red Rome x Red Gravenstein	125.53	127.53	126.53	Scarlet Spur x Golden Delicious	135.27	132.62	133.94	Oregon Spur x Red Gold	148.4	151.63	150.01
Law Red Rome x Golden Delicious	143.51	147.42	145.46	Scarlet Spur x Red Gold	140.5	137.49	138.99				
Law Red Rome x Red Gold	144.36	149.31	146.83								
Braeburn female parent			Ginger Gold female parent			Red Gravenstein female parent					
Braeburn x Ginger Gold	136.61	138.56	137.58	Ginger Gold x Red Gravenstein	133.42	135.34	134.38	Red Gravenstein x Golden Delicious	135.41	136.37	135.89
Braeburn x Red Gravenstein	131.52	134.55	133.03	Ginger Gold x Golden Delicious	136.38	141.53	138.95	Red Gravenstein x Red Gold	138.36	137.74	138.05
Braeburn x Golden Delicious	143.58	145.37	144.47	Ginger Gold x Red Gold	139.29	140.37	139.83				
Braeburn x Red Gold	148.43	147.37	147.9								
Golden Delicious female parent			Red Gold (V11)								
Golden Delicious x Red Gold	151.53	148.46	149.99								
Red Gold (V11)											
CD (5%)	3.71	2.89	3	CD (5%)	3.71	2.89	3	CD (5%)	3.71	2.89	3

Table 3: Fruit length (cm) of apple cultivars under open pollination

Genotypes	2021 year	2022 year	Pooled
Gala Must	8.49	8.66	8.58
Royal Gala	7.19	7.2	7.2
Early Red One	7.42	7.51	7.47
Law Red Rome	7.46	8.21	7.83
Scarlet spur	7.73	7.89	7.81
Oregon spur	9.2	9.38	9.29
Braeburn	5.42	5.73	5.58
Ginger Gold	6.35	6.66	6.51
Red Gravenstein	6.79	7.12	6.95
Golden Delicious	9.2	9.32	9.26
Red Gold	8.49	8.79	8.64
CD (5%)	0.55	0.41	0.33

Table 4: Fruit length (cm) of apple cultivars under planned hand pollination

Genotypes	2021 year	2022 year	Pooled	Genotypes	2021 year	2022 year	Pooled	Genotypes	2021 year	2022 year	Pooled
Gala Must female parent			Royal Gala female parent			Early Red One female parent					
Gala Must x Royal Gala	7.68	7.88	7.78	Royal Gala x Early Red One	7.44	7.69	7.56	Early Red One x Law Red Rome	7.55	7.83	7.69
Gala Must x Early Red One	7.37	7.12	7.24	Royal Gala x Law Red Rome	6.87	7.04	6.95	Early Red One x Scarlet spur	6.89	6.88	6.88
Gala Must x Law Red Rome	8.57	8.94	8.75	Royal Gala x Scarlet spur	7.27	7.34	7.3	Early Red One x Oregon spur	7.45	7.26	7.35
Gala Must x Scarlet spur	7.85	8.25	8.05	Royal Gala x Oregon spur	7.29	7.51	7.4	Early Red One x Braeburn	7.98	8.38	8.18
Gala Must x Oregon spur	7.4	7.87	7.63	Royal Gala x Braeburn	7.56	8.15	7.85	Early Red One x Ginger Gold	6.47	7.64	7.55
Gala Must x Braeburn	7.95	8.38	8.16	Royal Gala x Ginger Gold	6.38	6.56	6.47	Early Red One x Red Gravenstein	6.35	6.46	6.4
Gala Must x Ginger Gold	7.76	8.17	7.96	Royal Gala x Red Gravenstein	6.37	6.53	6.45	Early Red One x Golden Delicious	7.85	8.25	8.05
Gala Must x Red Gravenstein	6.57	6.76	6.66	Royal Gala x Golden Delicious	7.84	8.18	8.01	Early Red One x Red Gold	7.95	8.35	8.15
Gala Must x Golden Delicious	8.78	9.27	9.02	Royal Gala x Red Gold	7.89	8.34	8.11				
Gala Must x Red Gold	8.76	9.15	8.95								
Law Red Rome female parent			Scarlet Spur female parent			Oregon spur female parent					
Law Red Rome x Scarlet spur	6.83	7.32	7.07	Scarlet Spur x Oregon spur	6.78	7.28	7.03	Oregon Spur x Braeburn	7.63	7.88	7.75
Law Red Rome x Oregon spur	6.89	7.38	7.13	Scarlet Spur x Braeburn	7.93	8.53	8.23	Oregon Spur x Ginger Gold	7.78	8.27	8.02
Law Red Rome x Braeburn	7.1	8.39	7.74	Scarlet Spur x Ginger Gold	8.15	8.53	8.34	Oregon Spur x Red Gravenstein	7.45	7.63	7.54
Law Red Rome x Ginger Gold	6.95	8.06	7.5	Scarlet Spur x Red Gravenstein	6.47	6.66	6.56	Oregon Spur x Golden Delicious	9.12	8.91	9.01
Law Red Rome x Red Gravenstein	6.74	7.24	6.99	Scarlet Spur x Golden Delicious	7.13	7.32	7.22	Oregon Spur x Red Gold	9.2	9.34	9.27
Law Red Rome x Golden Delicious	7.64	8.48	8.06	Scarlet Spur x Red Gold	8.24	8.74	8.49				
Law Red Rome x Red Gold	7.77	8.56	8.16								
Braeburn female parent			Ginger Gold female parent			Red Gravenstein female parent					
Braeburn x Ginger Gold	6.23	6.55	6.39	Ginger Gold x Red Gravenstein	6.49	6.86	6.67	Red Gravenstein x Golden Delicious	7.32	7.91	7.61
Braeburn x Red Gravenstein	6.05	6.22	6.13	Ginger Gold x Golden Delicious	7.21	7.98	7.59	Red Gravenstein x Red Gold	7.63	8.16	7.89
Braeburn x Golden Delicious	6.76	7.65	7.2	Ginger Gold x Red Gold	7.37	8.13	7.75				
Braeburn x Red Gold	7.37	8.22	7.79								
Golden Delicious female parent			Red Gold (V11)								
Golden Delicious x Red Gold	8.78	9.11	8.95								
Red Gold (V11)											
CD (5%)	0.13	0.13	0.29	CD (5%)	0.13	0.13	0.29	CD (5%)	0.13	0.13	0.29

Table 5: Fruit diameter (cm) of apple cultivars under open pollination

Genotypes	2021 year	2022 year	Pooled
Gala Must	9.73	9.93	9.83
Royal Gala	8.42	8.65	8.54
Early Red One	7.9	8.13	8.01
Law Red Rome	7.32	7.66	7.49
Scarlet spur	8.7	8.87	8.79
Oregon spur	9.66	9.83	9.74
Braeburn	6.63	6.85	6.74

Ginger Gold	7.51	7.63	7.57
Red Gravenstein	8.05	8.25	8.15
Golden Delicious	9.58	9.73	9.66
Red Gold	8.88	9.13	9.00
CD (5%)	0.55	0.54	0.52

Table 6: Fruit diameter (cm) of apple cultivars under planned hand pollination

Genotypes	2021 year	2022 year	Pooled	Genotypes	2021 year	2022 year	Pooled	Genotypes	2021 year	2022 year	Pooled
Gala Must female parent				Royal Gala female parent				Early Red One female parent			
Gala Must x Royal Gala	8.56	8.89	8.72	Royal Gala x Early Red One	8.22	8.75	8.48	Early Red One x Law Red Rome	8.22	8.39	8.3
Gala Must x Early Red One	7.76	8.16	7.96	Royal Gala x Law Red Rome	7.76	8.23	7.99	Early Red One x Scarlet spur	7.62	7.82	7.72
Gala Must x Law Red Rome	9.34	9.64	9.49	Royal Gala x Scarlet spur	8.14	8.35	8.24	Early Red One x Oregon spur	7.73	7.92	7.82
Gala Must x Scarlet spur	8.86	9.21	9.03	Royal Gala x Oregon spur	8.21	8.42	8.31	Early Red One x Braeburn	8.43	8.84	8.63
Gala Must x Oregon spur	8.43	8.62	8.52	Royal Gala x Braeburn	8.62	8.86	8.74	Early Red One x Ginger Gold	7.97	8.19	8.08
Gala Must x Braeburn	8.95	9.25	9.1	Royal Gala x Ginger Gold	7.75	8.15	7.95	Early Red One x Red Gravenstein	7.14	7.31	7.22
Gala Must x Ginger Gold	8.86	8.94	8.9	Royal Gala x Red Gravenstein	7.41	7.96	7.68	Early Red One x Golden Delicious	8.31	8.51	8.41
Gala Must x Red Gravenstein	7.38	7.85	7.61	Royal Gala x Golden Delicious	8.95	9.19	9.06	Early Red One x Red Gold	8.36	8.68	8.52
Gala Must x Golden Delicious	9.68	9.91	9.79	Royal Gala x Red Gold	8.87	9.18	9.03				
Gala Must x Red Gold	9.62	9.81	9.71								
Law Red Rome female parent				Scarlet Spur female parent				Oregon spur female parent			
Law Red Rome x Scarlet spur	6.87	7.65	7.26	Scarlet Spur x Oregon spur	7.64	7.88	7.74	Oregon Spur x Braeburn	8.34	8.83	8.58
Law Red Rome x Oregon spur	7.41	7.85	7.63	Scarlet Spur x Braeburn	8.95	9.15	9.05	Oregon Spur x Ginger Gold	7.85	8.25	8.05
Law Red Rome x Braeburn	8.13	8.43	8.28	Scarlet Spur x Ginger Gold	9.11	9.31	9.21	Oregon Spur x Red Gravenstein	7.26	7.49	7.37
Law Red Rome x Ginger Gold	7.65	8.05	7.85	Scarlet Spur x Red Gravenstein	7.45	7.67	7.56	Oregon Spur x Golden Delicious	9.16	9.36	9.26
Law Red Rome x Red Gravenstein	6.82	7.17	6.99	Scarlet Spur x Golden Delicious	8.43	8.57	8.5	Oregon Spur x Red Gold	9.62	9.78	9.49
Law Red Rome x Golden Delicious	8.14	8.52	8.33	Scarlet Spur x Red Gold	9.32	9.45	9.38				
Law Red Rome x Red Gold	8.45	8.64	8.54								
Braeburn female parent				Ginger Gold female parent				Red Gravenstein female parent			
Braeburn x Ginger Gold	7.12	7.52	7.32	Ginger Gold x Red Gravenstein	7.80	7.96	7.88	Red Gravenstein x Golden Delicious	8.21	8.34	8.28
Braeburn x Red Gravenstein	6.92	7.22	7.07	Ginger Gold x Golden Delicious	7.94	8.29	8.12	Red Gravenstein x Red Gold	8.45	8.49	8.47
Braeburn x Golden Delicious	7.51	8.04	7.77	Ginger Gold x Red Gold	8.08	8.42	8.25				
Braeburn x Red Gold	7.86	8.24	8.05								
Golden Delicious female parent											
Golden Delicious x Red Gold	9.06	9.46	9.26								
Red Gold (V11)											
CD (5%)	0.88	0.53	0.59	CD (5%)	0.88	0.53	0.59	CD (5%)	0.88	0.53	0.59

Table 7: Fruit length/diameter ratio of apple cultivars under open pollination

Genotypes	2021 year	2022 year	Pooled
Gala Must	0.87	0.91	0.89
Royal Gala	0.85	0.91	0.88
Early Red One	0.94	0.97	0.95
Law Red Rome	0.84	0.89	0.86
Scarlet spur	0.87	0.82	0.84
Oregon spur	0.95	0.96	0.95
Braeburn	0.79	0.89	0.84
Ginger Gold	0.85	0.89	0.87
Red Gravenstein	0.84	0.89	0.86
Golden Delicious	0.96	0.97	0.96
Red Gold	0.96	0.98	0.97
CD (5%)	0.45	NS	NS

Table 8: Length diameter ratio under planned hand pollination

Genotypes	2021 year	2022 year	Pooled	Genotypes	2021 year	2022 year	Pooled	Genotypes	2021 year	2022 year	Pooled
Gala Must as female parent				Royal Gala female parent				Early Red One as Female parent			
Gala Must x Royal Gala	0.88	0.88	0.88	Royal Gala x Early Red One	0.90	0.87	0.88	Early Red One x Law Red Rome	0.91	0.93	0.92
Gala Must x Early Red One	0.94	0.87	0.90	Royal Gala x Law Red Rome	0.88	0.85	0.86	Early Red One x Scarlet spur	0.90	0.87	0.88
Gala Must x Law Red Rome	0.91	0.92	0.91	Royal Gala x Scarlet spur	0.89	0.87	0.88	Early Red One x Oregon spur	0.96	0.91	0.93
Gala Must x Scarlet spur	0.88	0.89	0.88	Royal Gala x Oregon spur	0.88	0.89	0.88	Early Red One x Braeburn	0.94	0.94	0.94
Gala Must x Oregon spur	0.87	0.91	0.89	Royal Gala x Braeburn	0.87	0.91	0.89	Early Red One x Ginger Gold	0.81	0.93	0.87
Gala Must x Braeburn	0.88	0.90	0.89	Royal Gala x Ginger Gold	0.82	0.80	0.81	Early Red One x Red Gravenstein	0.88	0.88	0.88
Gala Must x Ginger Gold	0.87	0.91	0.89	Royal Gala x Red Gravenstein	0.85	0.82	0.83	Early Red One x Golden Delicious	0.94	0.96	0.95
Gala Must x Red Gravenstein	0.89	0.86	0.87	Royal Gala x Golden Delicious	0.87	0.89	0.88	Early Red One x Red Gold	0.95	0.96	0.95
Gala Must x Golden Delicious	0.90	0.93	0.91	Royal Gala x Red Gold	0.88	0.90	0.89				
Gala Must x Red Gold	0.91	0.93	0.92								
Law Red Rome female parent				Scarlet Spur female parent				Oregon spur female parent			
Law Red Rome x Scarlet spur	0.99	0.95	0.97	Scarlet Spur x Oregon spur	0.88	0.92	0.90	Oregon Spur x Braeburn	0.91	0.89	0.90
Law Red Rome x Oregon spur	0.96	0.94	0.95	Scarlet Spur x Braeburn	0.87	0.93	0.90	Oregon Spur x Ginger Gold	0.99	1.00	0.99
Law Red Rome x Braeburn	0.87	0.99	0.93	Scarlet Spur x Ginger Gold	0.89	0.91	0.90	Oregon Spur x Red Gravenstein	1.02	1.01	1.01
Law Red Rome x Ginger Gold	0.90	1.00	0.95	Scarlet Spur x Red Gravenstein	0.86	0.86	0.86	Oregon Spur x Golden Delicious	0.99	0.95	0.97
Law Red Rome x Red Gravenstein	0.98	1.00	0.99	Scarlet Spur x Golden Delicious	0.84	0.85	0.84	Oregon Spur x Red Gold	0.95	0.95	0.95
Law Red Rome x Golden Delicious	0.93	0.99	0.96	Scarlet Spur x Red Gold	0.88	0.92	0.90				
Law Red Rome x Red Gold	0.91	0.99	0.95								
Braeburn female parent				Ginger Gold female parent				Red Gravenstein' female parent			
Braeburn x Ginger Gold	0.87	0.87	0.87	Ginger Gold x Red Gravenstein	0.83	0.86	0.84	Red Gravenstein' x Golden Delicious	0.89	0.94	0.91

Braeburn x Red Gravenstein	0.87	0.86	0.86	Ginger Gold x Golden Delicious	0.90	0.96	0.93	Red Gravenstein x Red Gold	0.90	0.96	0.93
Braeburn x Golden Delicious	0.90	0.95	0.92	Ginger Gold x Red Gold	0.91	0.96	0.93				
Braeburn x Red Gold	0.93	0.99	0.96								
Golden Delicious female parent											
Golden Delicious x Red Gold	0.96	0.96	0.96								
Red Gold (V11)											
CD (5%)	0.02	0.02	0.09	CD (5%)	0.02	0.02	0.09	CD (5%)	0.02	0.02	0.09

Conclusion

After this study, it is suggested that the varieties like braeburn variety could be used as pollinizer for early bearing varieties, Gala Must, Golden delicious and Oregon spur for mid-season varieties and Red Gold and Law Red Rome for late bearing varieties. The results further depicted that pollinizer varieties like Gala Must, Oregon Spur, Golden Delicious and Red Gold, when used as pollen donors have positively influenced the quality of apple under planned pollination. The pooled data reflected that one set of varieties i.e. Gala Must, Royal Gala, Scarlet spur, Oregon spur, Golden delicious and Red Gold had significant differences with other sets of varieties i.e. Early Red One, Law Red Rome, Braeburn, Ginger Gold and Red Gravenstein' in terms of the observed traits.

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