

## **Compatibility Studies in Exotic and Indigenous Almond Varieties/Selections under Temperate Conditions of Kashmir Valley**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors SM and AK designed the study, performed the statistical analysis, wrote the protocol and the final draft of the manuscript. Authors AA and ZR managed the analyses of the study. Authors SUN and ZAD managed the literature searches.*

*All authors read and approved the final manuscript.*

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### **ABSTRACT**

Almond is a self-incompatible plant and incompatibility are of the gametophytic type requiring pollen transfer between trees of different cultivars for fruit set. The present investigation was carried out for two consecutive years to evaluate cross-compatibility among selected varieties (three exotic) and selections (six indigenous) of a given segment of almond germplasm. Effective bloom period in the genotypes ranged between 8<sup>th</sup> March to 18<sup>th</sup> March and 7<sup>th</sup> March to 19<sup>th</sup> March in Mukhdoom, Shalimar, KD-03, KD-05, KD-06 and 23<sup>rd</sup> March to 31<sup>st</sup> March and 24<sup>th</sup> March to 2<sup>nd</sup> April in Pranyaj, Merced, Primorskij and Waris. Fruit set varied with each cross combination, initial fruit-set ranged from 5.55 per cent in Shalimar x KD-03 to 77.77 per cent in Waris x Shalimar in the first year and varied from 11.11 per cent in Merced x Shalimar to 85.71 per cent in Waris x KD-06 in second year. The highest final fruit set of 58.00 per cent was obtained in Merced x KD-05 as compared to lowest fruit set of 1.01 per cent recorded in Shalimar x KD-03 in the first year

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whereas the final fruit set ranged between 3.23 per cent to 66.00 per cent in Merced x Shalimar and Waris x KD-06 during the second year. Fruit set under open pollination varied from 9.00 to 60.00 per cent among different varieties/selections. No fruit set was observed in any genotype following selfing by bagging. Overall it is observed that the early blooming selections viz. Shalimar, KD-03, KD-05 and KD-06 exhibits maximum compatibility with most of the exotic and indigenous varieties/selections and obtained higher fruit set.

*Keywords: Almond; compatibility; exotic; indigenous; varieties; selections.*

## 1. INTRODUCTION

Flowering is one of the most important events on the life cycle in plants, with synchronization as a crucial factor. Almond is an important nut crop of Kashmir valley and is the earliest fruit species to bloom in spring [1]. Most almond breeding programmes aim to develop late-flowering cultivars to avoid frost damage and take advantage of higher temperatures which are favourable for pollination and fertilization. Almond crop probably present the widest range of flowering time among all the deciduous fruit and nut species. Effective pollination period in almond is longer than for other fruit trees [2]. It is an outcrossing species with strong self-incompatibility. The self-incompatibility is of gametophytic type [3]. In fact, self-incompatibility is one of the main causes of low productivity in almond and interplanting of pollinating cultivars has led to an improvement in production and productivity. Cross incompatibility is also common in almond [4]. The coincidence of flowering between compatible cultivars is essential for cross-pollination. Pollination is manifested by the successful transfer of pollen from the dehiscing anthers to the receptive stigma [1,5]. Pollination followed by fertilization is the important factor for almond production because the commercial part of the fruit is the seed that results from the fertilized ovule. Since almonds are pollinated primarily by honeybees, arranging pollinizers in close proximity to one another promotes maximum pollen transfer. Keeping in view the above facts, the present study was undertaken to determine the cross compatibility/ incompatibility between a set of almond genotypes.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Material and Location

The present investigations on compatibility and fruit set in different exotic (three) and indigenous (six) almond varieties were conducted at Dryland

Agriculture Research Station (DARS), SKUAST-Kashmir, Jammu and Kashmir. The experimental farm is situated at a latitude of 34°05'N and longitude of 74°50' E and at an altitude of 1640 m amsl with temperate region having cold conditions from November to February. The experimental was comprised of nine almond varieties viz. Pranyaj (V<sub>1</sub>), Merced (V<sub>2</sub>), Primorskij (V<sub>3</sub>), Mukhdoom (V<sub>4</sub>), Waris (V<sub>5</sub>), Shalimar (V<sub>6</sub>), KD-03 (V<sub>7</sub>), KD-05 (V<sub>8</sub>) and KD-06 (V<sub>9</sub>) planted in 1988. Plants of uniform size and vigour were selected randomly and all the trees were kept under similar cultural practices to ensure uniform growth.

### 2.2 Pollination Studies

#### 2.2.1 Open pollination

To determined fruit set under open pollination conditions two shoots in opposite directions were selected for each variety/selection and the number of flowers on each shoot was counted. All the selected shoots were left open for natural pollination to occur and per cent fruit set (initial and final) was determined.

#### 2.2.2 Natural self-pollination (by bagging)

Three branches on three sides having floral buds were selected and all the opened flowers and shrivelled buds were removed. Numbers of buds at popcorn stage left on each shoot were counted. These shoots were covered with muslin cloth bags, tied at the lower end and properly labelled and per cent fruit set was determined.

#### 2.2.3 Hand cross-pollination

Three branches on three sides having floral buds were selected and all the opened flowers and undeveloped buds were removed. Flowers at balloon or popcorn stage were emasculated, covered with muslin cloth bags, properly tied, labelled and counted. At the time of stigma receptivity, the bags were removed and

**Table 1. Crossing plan among different almond varieties**

♂ \ ♀	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub>	V <sub>4</sub>	V <sub>5</sub>	V <sub>6</sub>	V <sub>7</sub>	V <sub>8</sub>	V <sub>9</sub>
V <sub>1</sub>	V <sub>1</sub> V <sub>1</sub>	V <sub>1</sub> V <sub>2</sub>	V <sub>1</sub> V <sub>3</sub>	V <sub>1</sub> V <sub>4</sub>	V <sub>1</sub> V <sub>5</sub>	V <sub>1</sub> V <sub>6</sub>	V <sub>1</sub> V <sub>7</sub>	V <sub>1</sub> V <sub>8</sub>	V <sub>1</sub> V <sub>9</sub>
V <sub>2</sub>		V <sub>2</sub> V <sub>2</sub>	V <sub>2</sub> V <sub>3</sub>	V <sub>2</sub> V <sub>4</sub>	V <sub>2</sub> V <sub>5</sub>	V <sub>2</sub> V <sub>6</sub>	V <sub>2</sub> V <sub>7</sub>	V <sub>2</sub> V <sub>8</sub>	V <sub>2</sub> V <sub>9</sub>
V <sub>3</sub>			V <sub>3</sub> V <sub>3</sub>	V <sub>3</sub> V <sub>4</sub>	V <sub>3</sub> V <sub>5</sub>	V <sub>3</sub> V <sub>6</sub>	V <sub>3</sub> V <sub>7</sub>	V <sub>3</sub> V <sub>8</sub>	V <sub>3</sub> V <sub>9</sub>
V <sub>4</sub>				V <sub>4</sub> V <sub>4</sub>	V <sub>4</sub> V <sub>5</sub>	V <sub>4</sub> V <sub>6</sub>	V <sub>4</sub> V <sub>7</sub>	V <sub>4</sub> V <sub>8</sub>	V <sub>4</sub> V <sub>9</sub>
V <sub>5</sub>					V <sub>5</sub> V <sub>5</sub>	V <sub>5</sub> V <sub>6</sub>	V <sub>5</sub> V <sub>7</sub>	V <sub>5</sub> V <sub>8</sub>	V <sub>5</sub> V <sub>9</sub>
V <sub>6</sub>						V <sub>6</sub> V <sub>6</sub>	V <sub>6</sub> V <sub>7</sub>	V <sub>6</sub> V <sub>8</sub>	V <sub>6</sub> V <sub>9</sub>
V <sub>7</sub>							V <sub>7</sub> V <sub>7</sub>	V <sub>7</sub> V <sub>8</sub>	V <sub>7</sub> V <sub>9</sub>
V <sub>8</sub>								V <sub>8</sub> V <sub>8</sub>	V <sub>8</sub> V <sub>9</sub>
V <sub>9</sub>									V <sub>9</sub> V <sub>9</sub>

emasculated flowers were pollinated with the selected pollen parent as per the crossing plan (Table 1). The pollinated flowers were counted, labelled and covered again with muslin cloth bags to avoid contamination/injury and per cent fruit set (initial and final) was determined.

### 2.2.4 Observations recorded

After twenty days of pollination, the initial fruit set was worked out by the formula: dividing the number of flowers pollinated to the number of fruits set multiplied by 100.

$$\text{Initial fruit set} = \frac{\text{Total number of fruitlets}}{\text{Total number of flowers pollinated}} \times 100$$

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.

$$\text{Final fruit set} = \frac{\text{Total number of fruits at harvest}}{\text{Total number of flowers pollinated}} \times 100$$

Effective bloom period was calculated by counting the number of days from initial (10%) bloom to final bloom (90%) for each tagged plants. Data collected on various parameters were statistically analyzed as per the procedure given by Snedecor and Cochran [6].

## 3. RESULTS AND DISCUSSION

Fig. 1 exhibits synchronization of the effective bloom period among different almond varieties/selections, which has been identified as: Mukhdoom, Shalimar, KD-03, KD-05 and KD-06 where the bloom period ranged from 8<sup>th</sup> to 18<sup>th</sup> March in the first year and from 7<sup>th</sup> to 19<sup>th</sup> March in second year. Pranyaj, Merced, Primorskij and Waris exhibits effective bloom period from 23<sup>rd</sup> to 31<sup>st</sup> March and 24<sup>th</sup> March to 2<sup>nd</sup> April in first year

and second year, respectively. An important consideration while grouping varieties for cross-pollination is the effective bloom period and the coincidence of effective blooming period is essential to have maximum fruit set and compatibility [2]. The varieties/selections which were found to have maximum overlapping of the effective blooming period in present study are grouped as: group one: Mukhdoom, Shalimar, KD-03, KD-05, KD-06 and group two: Pranyaj, Merced, Primorskij and Waris. Kester, et al. (1990) reported that the duration and time of bloom may vary with each cultivar and year. Present findings are in agreement with the earlier findings of Kaska, et al. [7] and Dalal, et al. [8].

### 3.1 Fruit Set Under Cross Pollination

The initial and final fruit set obtained significant results in different cross combinations and the results are presented in Tables 2 and 3. The initial fruit set in different combinations ranged between 5.55 to 77.77 per cent in first year and 0.00 to 85.70 per cent in second year, however the final fruit set in different combinations ranged between 1.01 to 58.00 per cent in first year and from 0.00 to 66.00 per cent in second year.

Data presented in Table 2 depicts that during first year highest initial fruit set was obtained in Pranyaj x Merced (38.88%) which was significantly higher among the entire pollen source cross with Pranyaj, however lowest initial fruit set was recorded in Pranyaj x KD-06 (13.33%). Final fruit set ranged from highest of 30.00 per cent in Pranyaj x Merced to a lowest final fruit set of 4.28 per cent recorded in Pranyaj x Shalimar. During second-year initial fruit set ranged from a highest of 31.03 per cent (Pranyaj x Merced) to a lowest of 18.18 per cent (Pranyaj x KD-05) as compared to final fruit set ranging

from 22.29 per cent recorded in Pranyaj x Merced to 6.42 per cent recorded in Pranyaj x Shalimar.

Different pollen source crossed with Merced showed a significant effect on both initial and final fruit set during both the years of study (Tables 2 and 3). During first year, the initial fruit set ranged from 72.72 per cent (Merced x KD-05) to 10.00 per cent (Merced x Shalimar). The final fruit set was recorded maximum from a cross of Merced x KD-05 (58.00) as compared to a lowest final fruit set (5.90%) recorded in Merced x Shalimar. The highest initial fruit set during second year of study was recorded in Merced x KD-05 (60.77%) which differed significantly from other cross combination with Merced and the lowest initial fruit set was recorded in Merced x Shalimar (11.11%). Final fruit set in the second year varied significantly within a range of 42.00 per cent (Merced x KD-05) to 3.23 per cent (Merced x Shalimar). There was no fruit set in Merced x Primorskij during both the year. Sharafi [9] reported 9.1 per cent to 37.1 per cent fruit set in late blooming genotypes, 7.4 per cent to 29.4 per cent in medium blooming genotypes and 4.7 per cent to 23.1 per cent in early blooming genotypes of almond.

Different cross combinations of Primorskij varied significantly in respect of initial and final fruit set during both the year and in the first year

the initial fruit set showed the highest range of 52.63 per cent in Primorskij x KD-03 as compared to lowest 19.52 per cent in Primorskij x KD-05 (Table 2). Similar results were obtained in final fruit set, where Primorskij x KD-03 (39.00%) exhibited maximum fruit set as compared to the lowest fruit set recorded in Primorskij x KD-05 (8.00%). During second year, Primorskij x KD-03 showed highest initial (51.02%) and final (38.11%) fruit set whereas lowest fruit set both initial and final was recorded in Primorskij x KD-05 (23.07 and 7.80%, respectively).

Data presented in Tables 2 and 3 indicates a significant effect of different pollen source on Mukhdoom during both the years on initial and final fruit set. Maximum initial fruit set was recorded in Mukhdoom x KD-05 (63.33%) which differed significantly from the lowest initial fruit set recorded in Mukhdoom x Waris (17.00%). The final fruit set ranged from 48.00 per cent (Mukhdoom x KD-05) to 7.00 per cent (Mukhdoom x Waris) during first year. During second year, maximum initial and final fruit set was recorded in Mukhdoom x KD-05 (66.66% and 48.13%, respectively) and minimum initial and final fruit set was recorded in Mukhdoom x Waris (16.66% and 7.55%, respectively). Ortega, et al. [10] also reported similar results for fruit set with different cross combinations among 26 almond genotypes.

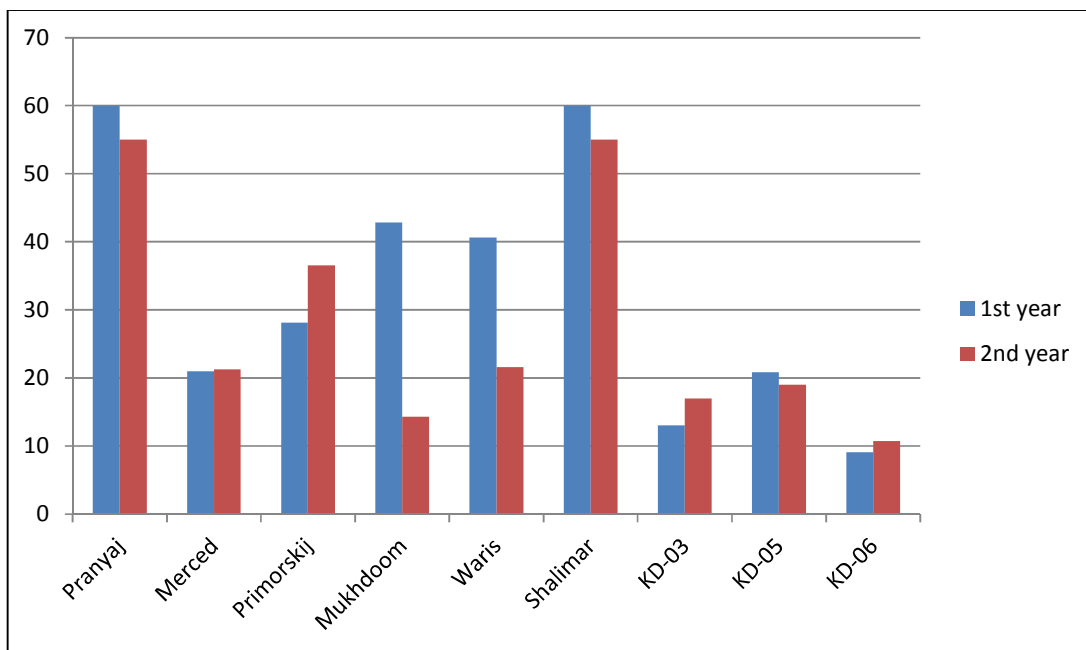


Fig. 1. Fruit set (%) under open pollination of different varieties/selections



**Table 2. Initial fruit set (%) of different cross combinations**

Varieties	Year	Pranyaj	Merced	Primorskij	Mukhdoom	Waris	Shalimar	KD-03	KD-05	KD-06	CD <sub>0.05</sub>
Pranyaj	1 <sup>st</sup> year	-	38.88	25.00	16.66	17.39	14.28	15.38	29.41	13.33	1.14
	2 <sup>nd</sup> year	-	31.03	18.75	12.50	23.38	21.42	21.87	18.18	28.57	1.60
Merced	1 <sup>st</sup> year	-	-	-	10.50	26.92	10.00	28.57	72.72	18.18	0.74
	2 <sup>nd</sup> year	-	-	-	15.15	23.44	11.11	27.77	60.77	25.00	1.52
Primorskij	1 <sup>st</sup> year	-	-	-	33.33	25.00	27.27	52.63	19.52	35.71	0.90
	2 <sup>nd</sup> year	-	-	-	38.09	25.00	27.92	51.02	23.07	30.90	1.73
Mukhdoom	1 <sup>st</sup> year	-	-	-	-	17.00	54.54	33.33	63.33	50.22	1.27
	2 <sup>nd</sup> year	-	-	-	-	16.66	40.26	40.23	66.66	62.50	1.64
Waris	1 <sup>st</sup> year	-	-	-	-	-	50.00	77.77	40.22	67.14	0.83
	2 <sup>nd</sup> year	-	-	-	-	-	48.23	68.00	60.00	85.71	0.90
Shalimar	1 <sup>st</sup> year	-	-	-	-	-	-	5.55	28.00	30.99	0.62
	2 <sup>nd</sup> year	-	-	-	-	-	-	0.00	30.00	33.33	0.67

**Table 3. Final fruit set (%) of different cross combinations**

Varieties	Year	Pranyaj	Merced	Primorskij	Mukhdoom	Waris	Shalimar	KD-03	KD-05	KD-06	CD <sub>0.05</sub>
Pranyaj	1 <sup>st</sup> year	-	30.00	20.00	10.98	12.39	4.28	9.00	19.23	9.33	0.82
	2 <sup>nd</sup> year	-	22.29	11.00	8.12	16.50	6.42	10.93	11.81	17.14	1.26
Merced	1 <sup>st</sup> year	-	-	-	7.11	11.60	5.90	20.00	58.00	8.18	0.49
	2 <sup>nd</sup> year	-	-	-	10.13	9.29	3.23	18.29	42.00	9.00	0.97
Primorskij	1 <sup>st</sup> year	-	-	-	21.00	10.24	15.00	39.00	8.00	25.12	1.21
	2 <sup>nd</sup> year	-	-	-	21.20	9.00	12.00	38.11	7.80	18.92	1.43
Mukhdoom	1 <sup>st</sup> year	-	-	-	-	7.00	37.00	21.00	48.00	34.11	1.02
	2 <sup>nd</sup> year	-	-	-	-	7.55	26.37	27.11	48.13	42.00	2.13
Waris	1 <sup>st</sup> year	-	-	-	-	-	32.00	51.00	26.21	41.00	0.91
	2 <sup>nd</sup> year	-	-	-	-	-	31.20	48.00	40.22	66.00	1.15
Shalimar	1 <sup>st</sup> year	-	-	-	-	-	-	1.01	15.28	18.98	1.38
	2 <sup>nd</sup> year	-	-	-	-	-	-	0.00	14.00	18.66	0.61

Highest initial and final fruit set in the first year of study was recorded in Waris x KD-03 (77.77% and 51.00%, respectively) followed by 67.14 per cent and 41.00 per cent, respectively in Waris x KD-06, whereas lowest initial and final fruit set was recorded in Waris x KD-05 (40.22% and 26.21%, respectively). In the second year, maximum initial and final fruit set was recorded in Waris x KD-06 (85.71% and 66.00%, respectively) and minimum initial and final fruit set was recorded in Waris x Shalimar (48.23% and 31.20%, respectively).

Initial and final fruit set of different cross combinations with Shalimar was significant during both the years (Tables 2 and 3). The initial fruit set ranged from 30.99 per cent (Shalimar x KD-06) to 5.55 per cent (Shalimar x KD-03) in the first year and ranged from 33.33 per cent (Shalimar x KD-06) to 30.00 per cent (Shalimar x KD-05) in the second year. There was no fruit set observed in Shalimar x KD-03 in second year of study. The final fruit set was recorded maximum in Shalimar x KD-06 (18.98%) and minimum in Shalimar x KD-03 (1.01%) in first year and maximum in Shalimar x KD-06 (18.66%) and minimum in Shalimar x KD-05 (14.00%). Earlier, Sharafi, et al. [11] investigated cross-compatibility among ten favourable almond genotypes and obtained similar results for fruit set.

### 3.2 Fruit Set Under Open Pollination and Self-pollination

The data presented in Fig. 1 depicts that maximum fruit set under open pollination conditions during the first year was recorded in Pranyaj (60.00%) and Shalimar (60.00%) which was significantly higher than other cultivars followed by Mukhdoom (42.85%) whereas minimum was recorded in KD-06 (9.09%). In the second year maximum fruit set was recorded in Shalimar (55.00%) followed by Pranyaj (53.00%) whereas minimum fruit set was recorded in KD-06 (10.75%). There was no fruit set in any of the genotypes when they were bagged for self-pollination (Fig. 1). In the previous studies, Ortega, et al. [10] and Sharafi, et al. [11] also observed less than 22.0 per cent fruit set under open pollination conditions.

### 4. CONCLUSION

From the above discussion, it is concluded that Mukhdoom, Shalimar, KD-03, KD-05, KD-06 were early-blooming selections and Pranyaj,

Merced, Primorskij and Waris were late bloomers. Early blooming selections viz. Shalimar, KD-03, KD-05 and KD-06 exhibits maximum compatibility with most of exotic and indigenous varieties/selections and obtained higher fruit set.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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