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Full length Research Paper

Analysis of compatibility relationships among some almond genotypes using fruit set and fluorescence microscopy

Yavar Sharafi[1]*, Jafar Hajilou[2], Seyyed Abol-Gasem Mohammadi[3] and Mohammad Reza Dadpour[4]

[1]Islamic Azad University of Maragheh Branch, Maragheh, Iran.
[2] Department of Horticulture, Faculty of Agriculture, University of Tabriz, Tabriz, 5166614766, Iran.
[3] Department of Agronomy and Plant Breeding, Faculty of Agriculture, University of Tabriaz, Tabriz, 5166614766.
[4]Agriculture and Natural Resources Research Center of East-Azarbaijan. Tabriz, Iran.

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Most of the Iranian almond cultivars are self-incompatible followed by pollination, fertilization, fruit set and lower yield problems. Therefore, selecting suitable cross-compatible cultivars for orchard establishment is necessary especially by new cultivars/genotypes obtained from breeding programs. In this study fruit set and pollen tube growth of ten late-bloom almond genotypes, obtained from a breeding program (D, E, F, I, G, L, K, O, P and Q) were investigated under filed and lab controlled pollination conditions. In order to study self-and cross-(in) compatibility they were pollinated by the pollens of overlap blooming-time genotypes in both conditions. Initial and final fruit set, fruit drop and some of the kernel traits were measured under filed condition. Measurements of pollen tubes at the style and in ovary were scored using fluorescence microscopy in lab, Results showed significant differences in some of the studied characters among crosses in both methods and Results confirmed each other in both methods. Fruit set percentage and pollen tube number in the ovary demonstrated that, all of the genotypes were self-incompatible but cross-(in) compatibility was not observed among them. In conclusion all of the genotypes could be used as a suitable polinizers for each others, regarding overlapping blooming-time of genotypes.

Key words: Almond, self-incompatibility, cross-incompatibility, fruit set, fluorescence microscopy.

INTRODUCTION

In fruit production industry self-incompatible cultivars are undesirable because, they cannot be grown in single-cultivar orchards; and their fruit set depends on the abundance of pollen transfer from other trees and finally produce lower yields. Self-incompatibility often occurs in fruit species of the genus *prunus* especially in sweet cherries and almonds (Milovic and Nicovic, 2007). However most of the commercial almond cultivars are gametophytical-self-incompatible therefore, successful pollination and fertilization are limiting factors for efficient almond production (Oukabli et al., 2000) because in this system self pollen tube growth stop in upper third of the styles and fertilization cannot take place successfully (Milovic and Nicovic., 2007). For this reason, high yields in almond need to plant at least 2 cross-compatible cultivars with overlapping blooming-time. Determination of self (cross)-compatibility relationships among cultivars/genotypes is one of the main objectives in almond breeding programs in the most almond producer countries such as Iran, in addition, determination of self (cross)-compatible cultivars/genotypes and their correctly plantation in the orchards, reduce orchard management costs and ensure pollination, fertilization, fruit set and producing consistent yields (Dicenta et al., 2002). Iranian

Correspondong Authors E-mail: yavarsharafi@iau-maragheh.ac.ir. Tel: +98 914 4200882, Fax: +98 421 3254506.

almond cultivars are self-incompatible so, knowledge the self- and cross-(in) compatibility of them is necessary for the future breeding programs and orchard establishment. Traditional filed and laboratory controlled pollination, flore-scence microscopy studies and evaluation of pollen tub growth have been used in order to identify the self- and cross-(in) compatibility of cultivars/genotypes (Hajilou et al., 2006; Socias i company and Felipe, 1994a), obtaining the effective pollination period (EPP) of cultivars (Ortega and Dicenta, 2004) and studding the effects of pollen types on the fruit set, fruit quality and seed quality (Kodad and Socias i company, 2008; Oukabli et al., 2000, 2002; Socias i Company and Felipe, 1987; Vargas et al., 2005). Recently molecular methods have been used to identify the self- and cross-(in) compatibility of cultivars-/genotypes (L´opez et al., 2004, 2006). Therefore, most of the self-and cross-(in) compatible cultivars of fruit trees have been identified by field and lab controlled pollination methods (Lopez et al., 2006; Hajilou et al., 2006). 26 cross-incompatible groups (CIG) of almond cultivars having the same self-incompatibility genotypes, have been reported using described methods (Boskovic et al., 2003; L´opez et al., 2004). The first S genotypes and cross-incompatibility groups of almond were detected through cross pollination tests in the field (Kester et al., 1994) and later in the laboratory based on pollen tube growth (L´opez et al., 2004, 2006). Socias i Company and Felipe (1992) studied the self-compatibility and autogamy in 'Guara' almond cultivar and demonstrated its self-compatibility using pollen tube growth and fruit set. Hadjilou et al. (2006) studied self-and cross-(in)compatibility of 5 commercial apricot cultivars using field and lab controlled pollination and specific primers consequently, showed 3 self-incompatible cultivars and 2 cross-incompatible group. Furthermore, many researchers studied the effects of pollen type on fruit traits (L´opez et al., 2006). Socias i Company et al. (2004) studied the effects of pollen type on fruit set in some self-compatible almond cultivars and reported that some self-compatible almond selections had higher fruit set following cross-pollination than self pollination. Dicenta et al. (2002) studied several fruit characteristics after self- and cross-pollination in several self-compatible almond cultivars and showed no differences between both pollination types for any of the studied fruit traits. The objectives of this research were to study pollen tubes reaching the ovary, fruit set and fruit characteristics in ten improved Iranian almond genotypes, analysis of their self-and cross-(in) compatibility relationships and clarify cross-compatible groups with high quality and quantity yields.

MATERIALS AND METHODS

Plant material

This research was carried out on 10 improved genotypes (D, E, F, I, L, K, G, O, P and Q) obtained from a breeding program that, grown in Sahand horticultural research station (belong to Agriculture and Natural Research Center of East Azarbaijan, Iran). Genotypes divided to 3 groups based on overlapping bloom time, group 1: D, F and Q, group 2: I, L and O, group 3: E, G, K and P. Inter crosses program were QxD, FxD, FxQ (in group 1), LxI, OxL, OxI (in group 2), and KxG, ExG, ExK, PxE, PxG and PxK (in group 3. Pollens collected from the flower buds gathered in 'D' stage, from orchards dried and maintained in freezer until using in the field and lab pollination time. Pollen germination was carried out in an *in vitro* medium with 1.5% agar and 15% sucrose, pollens were incubated at 22°C for 24 h under dark conditions and then their growth protected with chloroform. 7 microscopic areas were counted randomly for evaluation of germinated pollens percentage and length of pollen tubes was measured using an ocular micrometer. Experimental model was completely randomized design with 4 replicates.

Field experiments: fruit, nut and kernel traits

In spring 2008, for each cross 4 repeats (each direction of the tree) were regarded and in each repeat at least 2 branches with 60 - 100 flower buds at 'D' stage were bagged to prevent the entrance of foreign pollens. Flowers were pollinated when the pistils were acceptable for pollens (only safe and complete ones). Branches on each tree were labeled and the percentages of initial and final fruit set were determined 4 and 8 weeks after pollination, respectively. In summer 2008, for each cross, samples of 40 fruits were collected from the branches, and then dried at room temperature. In order to select the suitable polinizer for genotypes, effects of pollens on main fruit, nut and kernel traits (usually evaluate in almond breeding programs) were studied as indicated by Ortega et al. (2006).

Fluorescence microscopy

Branches having at least 60 flowers in 'D' stage were selected for each cross and transmitted to the lab. Flowers of branches were emasculated and placed in trays with the 5% socrus, kept under controlled conditions (22 - 23°C and 75 - 80% relative humidity) in the growth chamber. After 24 h, the emasculated pistils were self (cross)-pollinated and kept again under the same conditions for 72 h, then pistils were collected and fixed in FAA solution and prepared for fluorescence microscopy observation as indicated in Ortega and Dicenta (2006). For each pistil the number of germinated pollen grains in the stigma, the number of pollen tubes in the first, second and third section and so, in the ovary were determined by a fluorescent microscope.

Experimental design and statistical analysis

Experimental design was completely randomized (CRD) for self-pollinations and pollen viability tests (10 treatment (genotypes) in 4 repeat) and completely randomized block design (CRBD) for cross-pollinations (different treatment (cross in each group), 4 repeat and 4 block (each direction of the tree). Differences between genotypes and crosses were analyzed following SAS software. Mean values were analyzed by Duncan's multiple range test in the each group crosses separately.

RESULTS

Pollen tube growth and germination

The analysis of variance indicated the significant

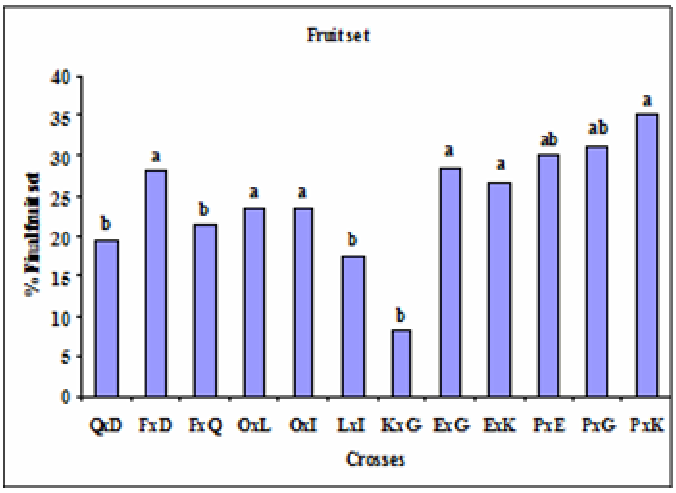

Figure 1. Means of the final fruit set percentage in the crosses (QxD, FxD,FxQ; group 1, LxI, OxL, OxI; group 2 and KxG, ExG, ExK, PxE, PxG and PxK group 3) (left genotypes pollinated by pollens of right ones and comparison of means carried out separately in each group crosses).

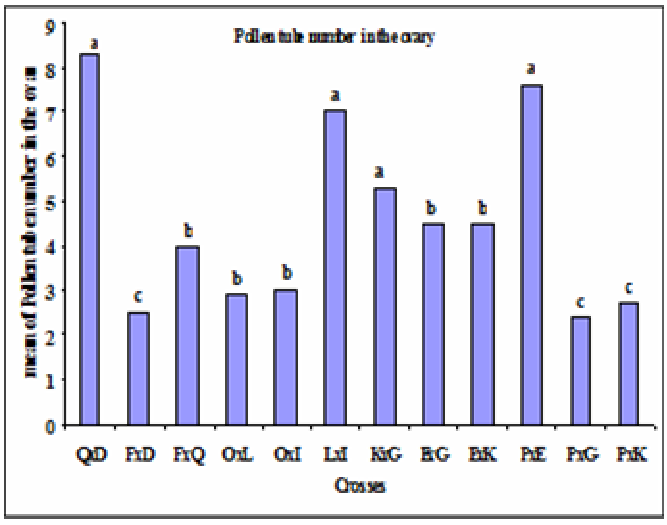

Figure 2. Means of the pollen tube number in the ovary of the crosses (QxD, FxD,FxQ; group 1, LxI, OxL, OxI; group 2 and KxG, ExG, ExK, PxE, PxG and PxK group 3). (left genotypes

differences in the percentage of pollen germination and pollen tube growth in all of ten studied genotypes at 5% level. Means of pollen germination percentage (Figures 1 and 2) were ranged among 26.5 - 78.9% in the *in vitro* medium. Respectively D: 78.9% (highest), E: 42.2%, F: 51.2%, G: 26.5% (lowest), I: 29.5%, L: 46.2%, K: 63.2%, O: 44.83%, P: 42.2% and Q: 65.86% (Tables 1 and 2). Also tables 1 and 2, showed the means of pollen tube length of the genotypes that, ranged among 155.2 - 737.2 µ, respectively D: 649.9 µ, E: 499.6 µ, F: 155.2 µ,

Table 1. Analysis of variances of the pollen germination percentage (PGP) and pollen tube length (PTL) in ten studied genotypes tested in the *in vitro* medium.

SOV	DF	PGP %	PTL(µ)
Genotypes	9	1066.9**	203035.6**
Experimental error	30	37	4734
CV		12.3	14.22

Table 2. Comparison of means of the pollen grain germination percentage (PGP) and pollen tube length (PTL) in 10 studied genotypes tested in the *in vitro* medium. (Means in each column with same letters are not significantly different at 5% level).

Genotype	Pgp %	Ptl (µ)
Q	65.86^{b}	737.2^{a}
D	78.9^{a}	649.9^{ab}
F	51.2^{c}	155.2^{de}
L	46.2^{c}	640.2^{ab}
I	29.5^{cd}	543.2^{bc}
O	44.83^{c}	116.4^{e}
E	42.73^{c}	499.6^{c}
K	63.2^{b}	685.8^{ab}
G	26.5^{d}	494.7^{c}
P	42.13^{c}	286.2^{d}

G: 494.7 µ, I: 543.2 µ, L: 640.2 µ, K: 685.8 µ, O: 116.5 µ (lowest), P: 286.2 µ and Q: 737.2 µ (highest). Pollen germination had not correlation with pollen tube length in the *in vitro* medium test (Tables 1 and 2). Means of germinated pollens percentage in the stigma of the self-pollinated crosses were 65 - 89.8%, respectively DxD: 79%, ExE: 81.8%, FxF: 74.5%, GxG: 89.8% (highest), IxI: 76.6%, LxL: 65.1% (lowest), KxK: 78.9%, OxO: 65.7%, PxP: 89.5% and QxQ: 72% (Tables 3 and 4). In addition, means of germinated pollens percentage in the stigma of cross-pollinated pistils were 51.9 - 89.5%, respectively QxD: 65%, LxI: 55.4%, KxG: 61.3% (lowest), ExK: 51.9%, ExG: 67.5%, FxD: 79.1%, FxQ: 81.4%, OxI: 89.5% (highest), OxL: 81.4%, PxE: 83%, PxG: 87.7% and PxK: 89.2% (Table 5). Means of the pollen tubes in the ovaries were 2.4-8.3 in the cross-pollinations, QxD: 8.3 (highest), LxI: 7, KxG: 4.5, ExK: 5.3, ExG: 4.5, F xD: 2.5, FxQ: 4, OxI: 2.9, OxL: 3, PxE: 7.6, PxG: 2.4 (lowest), and PxK: 2.7 respectively (Table 5). All of the crosses in each group, showed significantly differences in pollen grain germination percentage in the stigma, pollen tube number in the first, second and third section of the style and pollen tube number in the ovary (Table 5). The number of pollen tubes in the ovary had significant differences in the cross-pollination but, none of the pollen tubes reached to the ovaries in self-pollinated crosses. However, the pollen germination percentages in the

Table 3. Analysis of variances of pollen grain number in the stigma (PGN), pollen germination percentage in the stigma (PGP), number of pollen tubs in the first (style-1), second (style-2), third (style-3), section of style and number of pollen tubs in the ovary, in all of the genotypes pollinated by their own pollens. (**: significant in 1% level and *: significant in 5% level).

SOV	DF	PGN	PGP %	Style-1	Style-2	Style-3	ovary
Self-crosse	9	3636*	722**	756.6**	262.6**	12.5**	0
Experimental error	90	1441.5	84.4	224.5	73.8	1.9	0
CV		34	18	36	26	21	0

Table 4. Comparison of means of pollen grain number in the stigma (PGN), pollen germination percentage in the stigma (PGP), number of pollen tubs in the first (style-1), second (style-2), third (style-3), section of style and number of pollen tubs in the ovary, in all of the genotypes pollinated by their own pollens. (Comparison of means carried out separately in each group crosses).

Self-crosses	PGN	PGP	Style-1	Style-2	Style-3	Ovary
DXD	55.3^{ab}	79^{a}	17.5^{ab}	9^{ab}	0.5^{b}	0^{a}
QXQ	76.4^{a}	72^{b}	40.3^{a}	18.4^{a}	3.7^{a}	0^{a}
FXF	33.3^{b}	74.5^{a}	16.8^{b}	6^{ab}	0.1^{b}	0^{a}
OXO	76.1^{b}	65.7^{b}	22.5^{b}	1.7^{b}	0^{a}	0^{a}
LXL	101.2^{a}	65.1^{b}	38^{a}	4.7^{a}	0^{a}	0^{a}
IXI	80.8^{ab}	76.6^{a}	24^{ab}	5^{a}	0.7^{a}	0^{a}
GXG	47.2^{c}	89.8^{a}	16^{c}	2.7^{c}	0.7^{a}	0^{a}
KXK	73^{a}	78.9^{bc}	29^{ab}	12.2^{a}	0.7^{a}	0^{a}
EXE	70.5^{ab}	81.8^{ab}	32.4^{ab}	5.3^{b}	0^{a}	0^{a}
PXP	61.4^{b}	89.5^{a}	32.7^{a}	3^{c}	0^{a}	0^{a}

Table 5. Comparison of means of pollen grain number in the stigma (PGN), pollen germination percentage in the stigma (PGP), number of pollen tubs in the first (style-1), second (style-2), third (style-3), section of style and number of pollen tubs in the ovary; in the cross pollinations. (left genotypes pollinated by pollens of right ones and comparison of means carried out separately in each group crosses)

Crosses	PGN	PGP	Style-1	Style-2	Style-3	Ovary
QXD	95.9^{b}	65^{c}	48.8^{b}	29.6^{a}	14.2^{a}	8.3^{a}
FXD	106.3^{a}	79.1^{b}	55.6^{a}	20.6^{b}	9.1^{b}	2.5^{c}
FXQ	66^{ab}	81.4^{a}	35.3^{b}	15.8^{c}	7.8^{c}	4^{b}
OXI	39.1^{c}	89.5^{a}	25.4^{b}	13.7^{b}	6.5^{b}	2.9^{b}
OXL	68.2^{b}	81.4^{b}	25.6^{b}	13.7^{b}	6.5^{b}	3^{b}
LXI	88.3^{a}	55.4^{c}	35.5^{a}	26^{a}	15.6^{a}	7^{a}
EXK	129.2^{a}	51.9^{c}	53.9^{a}	29.3^{a}	16.6^{a}	5.3^{a}
EXG	107.3^{ab}	67.5^{a}	47.5^{ab}	27.4^{b}	11.8^{b}	4.5^{b}
KXG	78.5^{b}	61.3^{b}	35.3^{ab}	23,8^{c}	14.1^{a}	4.5^{b}
PXE	73.2^{c}	83^{ab}	43.1^{a}	25.3^{a}	15.8^{a}	7.6^{a}
PXG	93.3^{a}	87.7^{a}	44.8^{a}	18.2^{b}	5.1^{b}	2.4^{c}
PXK	59.1^{c}	89.2^{a}	27.6^{b}	11.7^{d}	6.1^{b}	2.7^{c}

stigma, in both of self and cross pollination had significant differences also, pollen germination in the stigma had not correlation with pollen tube number reaching the ovary, (Tables 3, 4 and 5). Data of Table 4 showed that highest pollen germination percentages in the stigma were observed in the stigmas witch received 40 - 60 pollen grains. Pollen germination and tube growth pattern showed in Figure 3 for some of the studied crosses.

Fruit and nut traits

Analysis of variances and comparison of the means were carried out in crosses of three groups separately

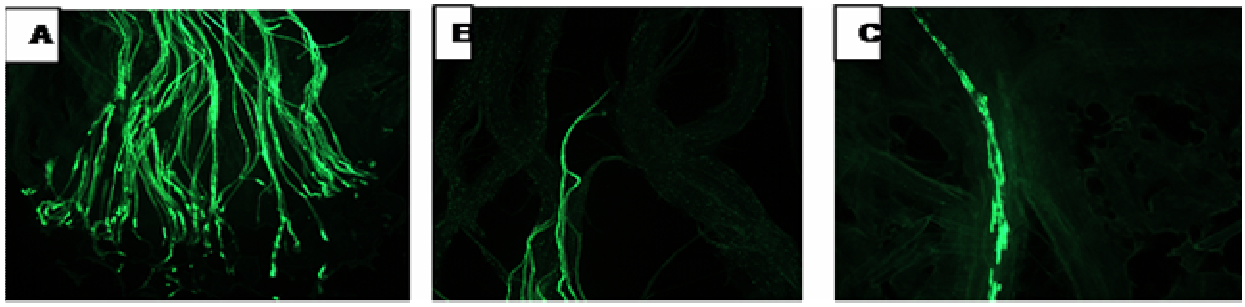

Figure 3. Pollen germination and tube growth pattern. (a) Pollens germinated in the stigma of the genotype P pollinated by itself pollens and tubs growth pattern in the style, (b) Deposition of pollen tube growth in the second section of the style in the self-pollinated G and(C) pollen tubes in the ovary of E pollinated by pollens of K.

Table 6. Comparison of means of the percentage of initial fruit set, final fruit set and fruit abscission. Means in each column with same letters are not significantly different at 5% level. (left genotypes pollinated by pollens of right ones and comparison of means carried out separately in each group crosses).

Crosses	Fruit set percentage		
	Initial	Final	Abscission
QXD	40^{b}	19.2^{b}	51.4^{ab}
FXD	48.7^{a}	28.12^{a}	40^{a}
FXQ	47.3^{a}	21.4^{b}	45.8^{ab}
OXL	62^{a}	23.4^{a}	62.2^{b}
OXI	62.3^{a}	23.4^{a}	61.6^{b}
LXI	47.8^{b}	17.6^{b}	62.4^{b}
KXG	67.5^{a}	8.2^{b}	88^{c}
EXG	55.3^{b}	28.6^{a}	54.3^{ab}
EXK	45.3^{c}	26.8^{a}	49.2^{a}
PXE	59.8^{b}	30.1^{ab}	47.6^{ab}
PXG	65.5^{a}	31.8^{ab}	49.7^{ab}
PXK	59^{b}	35^{a}	40^{a}

(genotypes that pollinated only with one type of pollens were not interfered). Analysis of variances showed differences at 5% level in some crosses for some of the studied fruit and kernel traits (data not shown). Initial and final fruit set percentage means were 40 - 67.52 and 8.2 - 34.96% in the crosses respectively, as well mean of fruit drop percentage was 40 - 88%. Final fruit set of crosses OxL, OxI, ExK and ExG were not shown significant difference among two pollen sources. Highest fruit set mean was observed in the crosses of group three, (Pxk; 35%, PxG; 31.8% and PxE; 30.1%) followed by lowest fruit absc-ission (Pxk; 40%, PxG; 49.78% and PxE; 47.6%), (Table 6). Crosses of group 2 were had highest fruit abscission (OxL; 62.2% and OxI; 61.5%). Initial fruit set percentage had not significant difference in group one crosses (FxD, FxQ and QxD), although their final fruit set and fruit abscission were have a few difference. Initial and final fruit set as so, fruit abscission were significantly different in the crosses of group two crosses (OxL, OxI and LxI) and group three crosses (PxE, PxK, PxG, ExK, ExG and KxG) (Table 6), although differences between crosses in each group were very little. Regarding the genotypes that pollinated at least by two types of pollens; nut and kernel weight, kernel size and kernel percentage were not significantly affected by pollen type in some crosses but affected very littlie in other some crosses (Table 7). For example, genotype E (pollinated by pollens of K and G) and F (pollinated by pollens of D and Q), showed not differences among 2 pollen type on nut and kernel weight and kernel size (Table 7). In the crosses of group 3, especially regarding PxE, PxK, PxG, kernel percentage, shape and weight were affected by pollen types but kernel size, thickness were not affected by different pollens (Table 7). Color of kernels was not affected by pollen type in none of the studied crosses (data not shown). Pollen type was not affected on nut shell hardi-ness in none of the studied crosses (Table 7) also blocks (each direction of the trees) had not showed significant effects on the studied traits of the fruit, nut and kernel (data not shown).

DISCUSSION

Results obtained from pollen tube growth pattern in the self-pollination in 10 studied genotypes demonstrated that all of the genotypes were self-incompatible because, in none of the self-pollinated crosses was stopped at the third upper section of the styles although, a few pollen tubes were received to the second or third section of the styles in some cases (Table 4). In the most case, pollen tube growth in the self-pollinated crosses were stopped at the third upper section of the styles although, a few pollen tubes were received to the second or third section of the styles in some cases (Table 4). Percentage of germinated pollens on the stigma was high in com-pared with the *in vitro* medium, this may caused by the ideal condition on the stigma versos to the *in vitro* conditions especially exist of proteins, amino acids and enzymes in the stigma. All of the crosses in each group, showed

Table 7. Comparison of means of the Pollen type effects on the kernel size, kernel thickness, kernel percentage (rate), kernel weight, nut weight, nut hardiness and kernel shape that evaluated by division the kernel length on its wight (L/W). (Left genotypes pollinated by pollens of right ones and comparison of means carried out separately in each group crosses).

Crosses	Kernel traits					Nut traits	
	Size	Thickness	Rate	Weight	L/W	Weight	Hardiness
QXD	4.6[b]	9.3[a]	0.7[a]	0.83[b]	1. 57[b]	1.18[b]	**9[a]**
FXD	7[a]	8.4[b]	0.67[b]	1.23[a]	1.8[a]	1.95[a]	**5[b]**
FXQ	8.7[a]	8.26[b]	0.63[c]	1.17[a]	1.75[a]	1.89[a]	**5[b]**
OXI	8.8[a]	8.12[b]	0.66[a]	1.2[b]	1.79[a]	1.89[b]	**7[a]**
OXL	8.3[a]	8.06[b]	0.64[b]	1.16[b]	1.72[a]	1.89[b]	**7[a]**
LXI	7[b]	9.9[a]	0.43[c]	1.36[a]	1.78[a]	3.35[a]	**3[b]**
EXK	4.6[b]	8.12[b]	0.7[a]	0.77[b]	1.54[a]	1.12[b]	**7[a]**
EXG	4.12[b]	8.8[a]	0.67[a]	0.77[b]	1.6[a]	1.16[b]	**7[a]**
KXG	6.5[a]	8.08[b]	0.49[b]	0.97[a]	1.53[a]	1.97[a]	**3[b]**
PXE	4.4[b]	7.58[a]	0.65[c]	.65[c]	2.18[c]	1[a]	**9[a]**

significantly differences in pollen grain germination percentage in the stigma, pollen tube number in the first, second and third section of the style and pollen tube number in the ovary (Table 5). Means of the pollen tubes in the ovaries were 2.4 - 8.3 in the cross-pollinations that, agreed with results obtained by Burgos et al. (1993) in different apricot cultivars. Pollen tube numbers were reduced from the stigma to the ovary in all of the self and cross-pollination systems (Tables 4 and 5).

In this study pollen tube number in the ovary and percentage of fruit set was not agree in the most crosses for example, regarding the crosses of group three (PxE, PxG and PxK) highest pollen tube number was observed in cross PxE (mean, 7.6) but highest fruit set was in the cross PxK (mean, 35%); this phenomenon represents variable environmental effects on different genotypes fruit set. High number of tubes in the ovaries and high fruit set, indicated the good compatibility of two genotypes for example, cross PxE had highest pollen tube number in the ovary and PxK had highest fruit set and could be introduce for orchard establishments (Figures 1 and 2). Pollen type in crosses of group 2 (OxL and OxI) had not significant effects on fruit set and pollen tube number in the ovary but crosses of group one (FxD and FxQ) showed very little differences (Figures 1 and 2). The main reason for the differences observed in fruit and kernel traits, may caused from the genetically differences among the genotypes or pollen types. In despite of our results, Socias i Company and Alonso (2004) detected cross-incompatibility of 'Ferragnès' and 'Ferralise' almond cultivars with controlled pollination and study of pollen tube growth by florescence microscopy. Many researchers studied the self-and cross-(in) compatibility of cultivars/genotypes using fruit set and fluorescence microscopy methods, and reported self-(in) compatible and cross-(in) compatible cultivars/genotypes in genus *prunus* species (Burgos et al., 1993; Hajilou et al., 2006; L´opez et al., 2004, 2006; Milatovic and Nicolic, 2007; Socias i Company and Felipe., 1992, 1994a). Burgos et al. (1993) studied self-and cross- (in) compatibility among 8 apricot cultivars using pollen tube growth in the laboratory and the percentage of fruit set in the orchard and finally resulted that five cultivars were self-incompatible but they were not observed cross-incompatibility among 25 cross-com-bination between cultivars. Those results agree with this work that, cross-incompatible groups were not observed among ten improved almond genotypes but all of them were self-incompatible.

Milatovic and Nicolic, 2007 studied self-(in) compatibility of 36 apricot cultivars using pollen tube growth and reported that, 22 cultivars were self-compatible and 14 cultivars were self-incompatible. Ortega and Dicenta (2006) studied the pollen tube growth pattern in the homozygous and heterozygous self-compatible almond individuals and showed that, in the heterozygous self-compatible almonds, rate of the pollen tube growth was high in compared with heterozygous ones and they related high fruit set of them for rapid pollen tube growth and high pollen tubes reaching to ovary. Ortega et al. (2004) following field studies showed that, although 'Marcona' cultivar and 'S_{5133}' genotype had similar pollen tubes in the style but, fruit set of 'Marcona' was higher than 'S_{5133}'. This phenomenon expresses interfering of other factors (etc of pollen tube number) in the fruit setting processes. Alonso and Socias i Company (2005), Socias i Company et al. (1976) and Dicenta et al. (2002c), following self-pollination and cross-pollination of self-compatible and self-incompatible almond genotypes found that, self-compatible almonds had a very low number of pollen tubes at the base of their styles after self-pollination and very slow growth rate (in despite of this work that, all of the genotypes were self-incompatible). Many researchers studied the effects of

pollen type on the fruit, nut and kernel traits and reported very inconsistent results; some of them reported significantly positive effects of pollen type on fruit traits and other some reported reverse results (Ortega et al., 2006). Vargas et al. (2005) indicated that fruits from open pollination in 34 self-compatible seedlings had higher weight in-shell, kernel weight, nut and kernel size in despite of self-pollination. Oukabli et al. (2002) observed a reduction of nut and kernel weight and kernel thickness in fruits from self-pollination of the self-compatible almond cultivar 'Tuono' in compared with cross-pollination with different cultivars. Furthermore, Socias i Company et al. (2004) demonstrated that some self-compatible almond selections had higher fruit sets following cross-pollination than after self-pollination and attributed the results to the different ability of set self-fruits instead of the influence of the pollination treatment. Consequently, in this work pollen tube number in the ovary, initial and final fruit set of cross-pollination groups showed that, all of the genotypes were cross-compatible and could pollinate each other regarding the overlapping time of blooming because, in none of the crosses final fruit set was 0% (0% final fruit set in a cross shows the cross-incompatibility of their pollens and pistils).

Conclusion

This research concluded that 10 studied almond genotypes were self-incompatible but cross-incommutability was not observed among genotypes and so, all of the genotypes could be used in breeding programs or orchard establishment for pollination each other based on the objectives. Moreover, based on the pollen tube number in the ovary, fruit set and fruit abscission percentages; group three genotypes (E, K, G and P) were constituted the best cross-compatible group for using as polinizers to each other especially, PxE and PxK compositions.

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REFERENCES

Alnos JM, Socias I, Company R (2005). Differential pollen tube growth in inbred self-compatible almond genotypes. Eupytica, 23: 207-213.

Borgus L, Berenguer T, Egea J (1993). Self-and cross-compatibility among apricot cultivars. Hort. Sci., 28: 148-150.

Bosković R, Tobutt KR, Battle I, Duval H, Martinez-Gomez P, Gradziel TM (2003). Stylar ribonucleases in almond: correlation with and prediction of incompatible genotypes. Plant Breed, 122: 70-76.

Dicenta F, Ortega E, Ca´novas JA, Egea J (2002c). Self-pollination vs. cross-pollination in almond: pollen tube growth, fruit and fruit characteristics. Plant Breed, 121: 163-167.

Dicenta F, Ortega E, Martı´nez-Go´mez P, Bos˘kovic´ R, Tobutt KR. (2002b). Comparison of homozygous and heterozygous self-compatible seedlings in an almond breeding programme. Euphytica 124: 23–27.

Hajilou J, Grigorian V, Mohammadi SA, Nazemieh A, Romero C, Vilanova S, Burgos L (2006). Self- and cross- (in) compatibility between important apricot cultivars in northwest Iran. Hort. Sci. Biotech., 81(3): 513-517.

Kester DE, Gradziel TM, Micke WC (1994). Identifying pollen incompatibility groups in California almond cultivars. J. Am. Soc. Hort. Sci., 119: 106-109.

Kodad O, Socias i Company R (2008). Fruit quality in almond as related to the type of pollination in self-compatible genotypes. J. Am. Soc. Hort. Sci., 133: 315-475.

Lopez M, Jose F, Vargas FJ, Battle I (2006). Self-(in)compatibility almond genotypes; a review. Euphytica, 150: 1-16.

Lopez M, Mnjja M, Rovira M, Collins G, Vargas FJ, Arus, P, Battle I (2004). Self-incompatibility genotypes in almond re-evaluated by PCR, stylar ribonuclease analysis and controlled pollination. Theor. Apple. Genet., 109: 954-964.

Milatovic D, Nicolic D (2007). Analysis of self-(in) compatibility in apricot cultivars using fluorescence microcopy. J. Hort. Sci. Biotech., 82: 170-174.

Ortega E, Dicenta F (2004). Effective pollination period in almond cultivars. Hort. Sci., 39: 19-22.

Ortega E, Dicenta F (2006). Self-fertilization in homozygous and heterozygous self-compatible almonds. Hort. Sci., 164: 1-6.

Ortega E, Egea J, canovas JA, Dicenta F (2002). Pollen tube dynamics following half and fully compatible pollination in self-compatibile almond cultivars. Sex. Plant. Reprod., 15: 47-51.

Ortega E, Martinez-Garca P, Dicenta F (2006). Influence of self-pollination in fruit quality of autogamous almonds. Sci. Hort., 109: 293-296.

Ortega E, Martinez-Garca P, Dicenta F, Boskovic R, Tobutt R (2002). Study of self-compatibility in almond progenies from self-fertilization by florescence microscopy and stylar ribonuclease assay. Acta. Hort., 591: 229-232.

Oukabli A, Lansari A, Walali A, Abousalim A, Egea J, Michaux-Ferrier N (2002). Self and cross pollination effects on pollen tube growth and fertilization in self-compatible almond (*prunus dulcis*) Tuono. J. Hort. Sci. Biotech., 75: 739-744.

Oukabli A, Lansari A, Walali-Loudiyi DE, Abousalim A (2000). Effects of controlled self-pollination and cross-pollination on fruit set, embryocal traits in the self-compatible almond cv 'TUONO, Acta. Hort., 591: 429-435.

Socias I, Company R, Alonso JM (2004). Cross-incompatibility of 'Ferragnès' and 'Ferralise' and pollination efficiency for self-compatibility transmission in almond. Euphytica, 135: 333-338.

Socias I, Company R, Felipe AJ (1987). Pollen tube growth and fruit set in a self- compatible almond selection. Hort. Sci., 22: 113-116.

Socias I, Company R, Felipe AJ (1992). Self-compatibility and autogamy in 'Guara' almond. J. Hort. Sci., 67: 313-317.

Socias I Company R, Felipe AJ (1994a). Cross-incompatibility of Ferragne`s and Ferralise: implications for self-compatibility transmission in almond. Acta Hort., 373: 153-156.

Socias I Company R, Alonso JM, Go´mez Aparisi J (2004). Fruit set and productivity in almond as related to self-compatibility, flower morphology and bud density. J. Hort. Sci. Biotechnol., 79: 754758.

Vargas FJ, Clave J, Romero MA (2005). Fruit size in self and open pollination condition in the self-compatible almond seedling. Book of abstract of IV international symposium on pistachios and almonds. Tehran. Iran, p. 61-62.