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Flower characteristics and sexual compatibility of Italian olive cultivar Coratina under Syrian coast conditions

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Abstract. *The study was conducted for four years (2016 to 2019) in Olive germoplasm collection at Bouka, Latakia, Syria, to evaluate flower characteristics and sexual compatibility of olive cultivar Coratina under Syrian coast conditions. "Coratina" was characterized by low level of pistil abortion, average number of flowers per inflorescence and good pollen germinablity. ISI of "Coratina" showed that this cultivar was highly self- incompatible. A new threshold depends on flowering load and final fruit set were adapted to evaluate pollinizers. The two autochthonous olive cultivars "Khodeiri" and "Dermlali" were good pollinizers for "Coratina" but with some annual differences in pollination efficiency. Reverse pollination results confirmed that "Khoderi" is inter-compatible with „Coratina" in both directions. It is suggested to plant "Coratina" in mixed orchards with "Khoderi" because they're inter-compatible, having regular bearing habit and overlapping in flowering period.*

Keywords: *Olea europaea* L., pistil abortion, pollination, Index of self-incompatibility (ISI)

Introduction

Olive is one of the most important fruit trees in Syria. Olive cultivation is closely related to the ancient and present Syrian culture and traditions. The Syrian coast is an important area for olive production; two olive cultivars ("Khodeiri" and "Dermlali") occupy the most cultivated area in the Syrian coast which contain several germoplasm collections established in order to study and evaluate local and imported olive cultivars from different environments.

Reproductive behavior is important because flowering and fruit set are the initial indices of yield and there is no yield without flowers and fruit set. Self- and cross- compatibility took authors' attention, so many studies were conducted to determine compatibility and select the optimum pollinizers for olive cultivars (Seifi et al., 2011; Koubouris et al., 2014; Sanchez-Estrada and Cuevas, 2018). Till now, Self incompatibility Locus (S-Locus) in olive still un-known. Although most recent studies reported that Sporophytic SI as the SI type acting in olive, but there were differences between authors in the number of alleles controlling this phenomenon (Breton et al., 2014; Saumitou-Laprade et al., 2017).

Until the full discovery of S- Locus, controlled crosses and fruit set estimation are the most common methods for compatibility evaluation under field conditions. Many studies reported the significance of cross pollination over self-pollination even in self-compatible cultivars such as "Leccino" and "Oblica" (Selak et al., 2014). Seifi et al. (2011) found that "Frantoio" is self- incompatible, but cross- compatible (as a receptor) with "Koroneiki" and "Barnea".

Italian olive cultivar "Coratina" was studied by Mahfoud (2018). This cultivar produced the highest yield compared to 23 local and imported cultivars in the olive germoplasm collection in Bouka, province of Latakia, Syria; this yield was also good and stable with high oil content. This cultivar was also characterized by tolerance to olive peacock eye disease. To our knowledge, no previous study dealing with compatibility evaluation of "Coratina" with Syrian cultivars has ever been done. This work aimed to evaluate flower characteristics, self- and cross- compatibility of "Coratina" with olive cultivars in Syrian coast "Khodeiri" and "Dermlali".

Material and methods

Study area

Experimental orchard: The study was conducted during four consecutive seasons 2016 to 2019 in the olive germoplasm collection at Bouka center for research and plant production, Latakia, Syria.

Plant material: For the purpose of the study an Italian olive cultivar "Coratina" and two autochthonous cultivars "Khodeiri" and "Dermlali", the most cultivated olives in the Syrian coast were used. All the trees were at the same age (about 32 years) and under rain fed conditions.

Flower characteristics: Samples of "Coratina" were taken (30 inflorescences in 2016 and 50 in 2017 and 2019) randomly at the white bud stage from four trees in 2016 and three trees in 2017, 2018 and 2019. In 2018 a total of 75 inflorescences were sampled as follows: 25 from the apical, 25 from the middle and 25 from the basal position of one-year branches distributed around the canopy of the trees in order to study the effect of position on branch on flower gender. Pistil abortion (%) and average number of flowers per inflorescence were calculated.

Phenological phases: Extending of flowering periods for the studied cultivars were determined by determining the beginning and the end of flowering for each cultivar.

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Pollen germination: Pollen grains were extracted from all studied cultivars and cultured immediately in 2016 and 2019 but stored for several days after extraction in 2017 and 2018 in the refrigerator until studying. Culturing media were according to Ferri et al. (2008) with some modifications: commercial sugar 15%, 5ppm boric acid, 0.6% agar. Pollens were kept in the dark for 24 hours at 25°C. Pollen germination was observed in 3 fields in each petri dish (four for each cultivar); every field contains more than 50 pollen (Koubouris et al., 2009).

Self and cross- compatibility

2016 season: A primary study was conducted to investigate the self-fertility of "Coratina". Four trees were selected for high flowering. Two one-year branches on each side of the trees were tagged at white bud stage; inflorescences were counted and unified by removing the additional inflorescences from the studied branches. One of the two branches was closed using white paper bags to force self-pollination and the other kept unclosed for open (free) pollination. After fruit setting papers were removed and Index of self-incompatibility was calculated according to (Lioyd, 1965):

ISI= number of fruits obtained by self-pollination / number of fruits obtained by free pollination

Fruit numbers were taken at the end of June when the massive fruit abscission ended and shot-berries were excluded. ISI was evaluated according to Zapata and Arroyo (1978).

2017, 2018 and 2019 seasons: The experiment was designed to investigate the cross-compatibility between "Khodeiri"- "Dermlali" (pollinizers) and "Coratina" (receptors) as follows: Three trees of uniform size and high flowering of "Coratina" were chosen. On each tree four one-year-old branches on each side were selected with the same number of inflorescences (additional inflorescences were removed).

Pollination treatments

Self-pollination: branches were enclosed at the white bud stage with white paper bags.

Cross-pollination: branches of "Coratina" were enclosed at the white bud stage with white paper bags. At full flowering stage of "Coratina", pollination was done by opening the bags and immediately transferring flowering branches (with open flowers) of the pollinizer cultivar into the bag and re-closing it and shaking the bags to ensure pollen dispersal.

Open-pollination: branches were kept unclosed for open (free) pollination.

No emasculation was done in order to simulate field conditions. Initial fruit set was measured 30 days after full bloom, final fruit set at the end of June. Fertility index (R) was calculated according to the following formula adapted from (Moutier, 2002):

R= number of fruits in the case of cross-pollination / number of fruits in the case of free pollination

Table1. Pollinizer's evaluation depending on fertility index (R) adapted from (Moutier, 2002)

	Cross pollination		
R	0.00-0.33	0.33-0.66	0.66-1.00
	Bad pollinizer	Passable pollinizer	Good pollinizer

Pollinizers were classified depending on Table 1 (Moutier, 2002).

It is worth mentioning that 2018 season was an off year of "Dermlali", which is a biennial bearing cultivar, so we introduced flowering shoots of "Dermlali" from another field on the same day of pollination in the morning.

In 2018 season, reverse pollination was performed between "Khoderi" (♀) and "Coratina" (♂) as follows: Three trees of "Khoderi" were chosen and three one-year-old branches were tagged on every side of the tree (12 on each tree). Emasculation of the flowers was performed by removing the petals and stamens two to three days before flower opening. Flowers of two branches were emasculated and enclosed by white paper bags, while the third one was kept without emasculation or bagging. Pollination was performed by transferring branches with open flowers of "Coratina" into the bags at the beginning of flowering of „Khoderi", closing the bags and shaking to ensure pollen dispersal. Self-pollination was performed in the same way but by transferring flowering branches of "Khoderi". The third branch on each side of the tree was left for open pollination after counting the flowers and unifying them in all branches. Final fruit set was determined at the end of June.

Metrological data: Average monthly maximum and minimum temperature and rainfall were obtained from Sit-Kheris station located less than 8km from the experimental orchard.

Experimental design and statistical analysis: Pollen germination experiment was designed as completely randomized design with three treatments (cultivars), each treatment replicated four times. Flower characteristics and pollination were designed as completely randomized blocks with three replications. Data were root transferred when necessary, and subjected to ANOVA. Means were separated using Duncan multiple range test (P≤0.05) using CoStat version 6.400 Copyright(c) 1998-2008 CoHort software, CA, USA.

Results

Meteorological data

Figure 1 shows that the winter of 2016-2017 was colder than other seasons, while 2017- 2018 winter was relatively warm. Precipitations were over 700mm for all study years but weren't distributed in the same way (Figure 2). Precipitation was almost absent in February 2017. The spring of 2019 was characterized by high precipitation, but it stopped in May, resulting in dry weather in May and June of 2019 season.

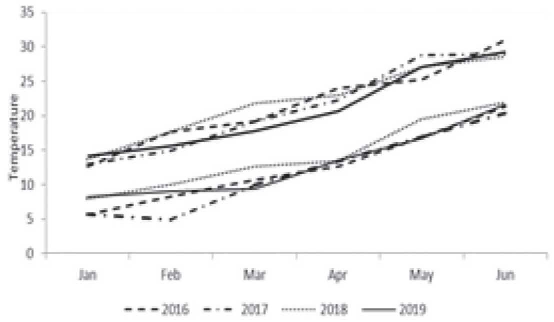

Figure 1. Monthly minimum and maximum temperature (°C) in the study area for the period 2016-2019

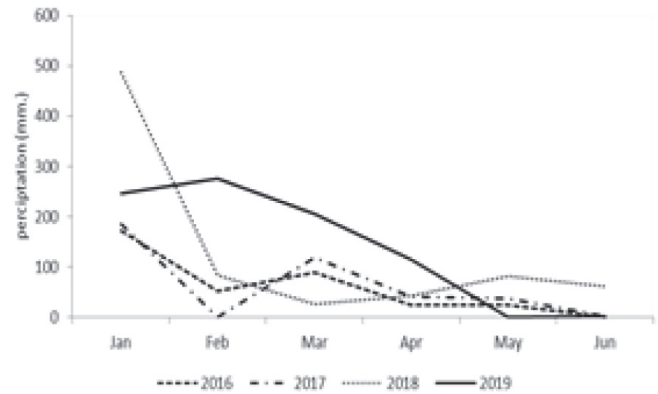

Figure 2. Mean monthly precipitation (mm) in the study area for the period 2016-2019

Flower characteristics and Phenological phases

Average number of flowers per inflorescence was low to medium in all study seasons (Figure 3B) with significant decrease in 2017 compared to other seasons. On average, the number of flowers per inflorescence for "Coratina" was 16.8. Both 2016 and 2019 seasons were characterized by high level of pistil abortion, while pistil abortion was significantly lower in 2017 and 2018 seasons (Figure 3A). In general, "Coratina" was characterized by low level of pistil abortion which was ~16% on average.

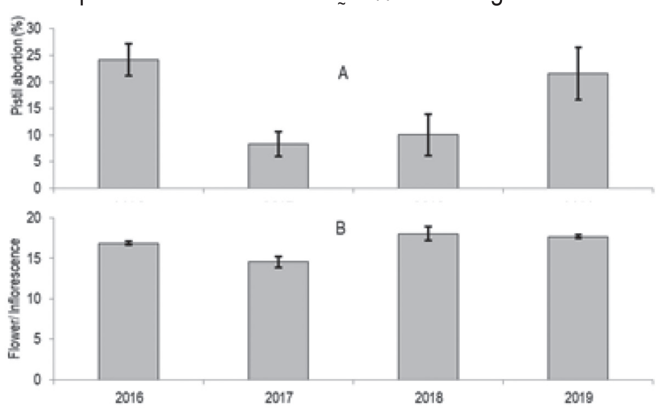

Figure 3. Pistil abortion (%) and the average number of flowers per inflorescence for olive cultivar "Coratina" for the consecutive seasons 2016-2019

Although pistil abortion decreased slightly in the middle of the branches, there were no significant differences between the three positions in pistil abortion (data are not shown). Phenological stages were highly different between seasons, especially between 2018 and 2019 seasons (Figure 4), but were synchronized in the same year. Flowering period of "Khoderi" was the longest and synchronized with "Coratina" by 13, 14 and 11 days in 2017, 2018 and 2019, respectively. Generally, flowering periods of "Khoderi" overlapped "Coratina" flowering in all seasons. "Dermlali" flowering periods were also synchronized with "Coratina" even though it was not determined in 2018 season.

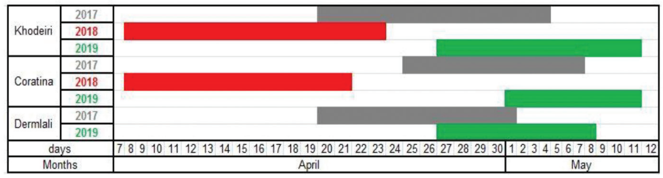

Figure 4. Flowering period of the olive cultivars "Khoderi", "Coratina" and "Dermlali" in 2017, 2018 and 2019 seasons (*Dermlali flowering period was studied for 2017 and 2019 seasons only)

Pollen grain germination

Figure 5 shows that the highest pollen germination was of "Coratina" pollens followed by "Khodeiri" without significant differences in 2016. No significant differences were obtained between all cultivars in 2017. In 2018 "Khodeiri" pollens had the highest germination ratio and "Dermlali" had the lowest. In 2019, pollen germination (%) was high in both "Khodeiri" and "Coratina". No sign of male sterility was observed for any of the studied cultivars.

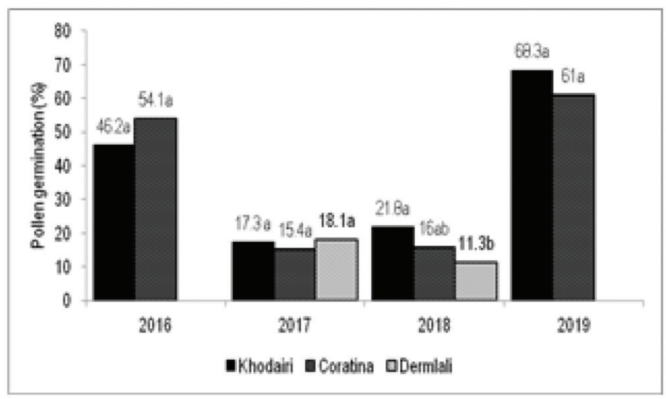

Figure 5. Pollen germination (%) of olive cultivars "Khoderi", "Coratina" and "Dermlali" in 2017 and 2018 seasons for "Dermlali" and for all studied seasons (2016-2019) for all other cultivars (*Different letters in the top of the columns indicated significant difference at $p<0.05$ between cultivars)

Self and cross-compatibility

Data obtained from the 2016 experiment showed severe self-incompatibility of "Coratina" (ISI= 0.1) (data are not shown). This highlights the importance of finding pollinizers in order to increase fruit set to commercial level.

Initial and final fruit set of 2017, 2018 and 2019 seasons

Initial fruit set: Open pollination produced the highest initial fruit set in 2017 followed by pollination with "Khodeiri" without significant differences between the two types of pollination (Table 2). Self-pollination produced the lowest initial fruit set. In 2018, initial fruit set resulting from cross-pollination with "Khodeiri" was the highest, but without significant differences with open and cross pollination with "Dermlali". Similar to 2017, self-pollination produced the lowest initial fruit set. In 2019 open pollination produced the highest initial fruit set and self-pollination produced the lowest. "Dermlali" was not studied in 2019 season.

Final fruit set: The final fruit set of 2017 and 2018 seasons followed the same behavior of the initial fruit set. Analysis of variance between seasons (2017 and 2018) showed no significant differences in final fruit set obtained from self and cross-pollination with "Dermlali", but there were significant differences in final fruit set obtained from open and cross-pollination with "Khodeiri".

Table 2. Initial, final and fruiting set of "Coratina" cultivar as affected by different types of pollination

Pollinizer	2017		2018		2019	
	IFS	FFS	IFS	FFS	IFS	FFS
Khodeiri	7.73[a]	6.18[a]	5.24[a]	1.62[a]	9.02[a]	3.25[a]
Dermlali	2.55[b]	1.99[b]	4.32[a]	2.11[a]	-	-
Open	9.91[a]	7.61[a]	5.04[a]	2.60[a]	9.06[a]	2.25[a]
Self-pollination	0.57[c]	0.52[c]	0.50[b]	0.00[b]	0.12[b]	0.02[b]

*IFS- initial fruit set (%), FFS- final fruit set (%); Different letters in the same column indicated significant difference (p<0.05)

It is clear from (Table 2) that in 2018 there was a massive fruit drop in all treatments. All fruits resulting from self-pollination abscised. The highest fruit abscission in cross-pollination treatments was of cross-pollination with "Khodeiri" (about 69% of fruit were dropped) followed by "Dermlali" and the lowest fruit drop was in open pollination treatment. This phenomenon was less severe in 2017, which is characterized by more retained fruits. Like 2018 season, 2019 was characterized by high percentage of fruit abscission. Almost 64-75% of the fruits resulting from cross-pollination with "Khodeiri" and open-pollination abscised, respectively.

Evaluation of pollinizers

Different performance of the two pollinizers used in this study was observed depending on the R-index. Table 3 shows that "Khodeiri" was a good pollinizer in 2017 and 2019 but passable in 2018, while "Dermlali" was evaluated as bad pollinizer in 2017 and good in 2018.

Table 3. Fertility index (R) and evaluation of three pollinizers for "Coratina" cultivar

Pollinizers	Fertility index (R)					
	2017	Evaluation	2018	Evaluation	2019	Evaluation
Khoderi	0.81	good	0.49	passable	1.44	good
Dermlali	0.26	bad	0.81	good	-	-
Coratina	0.07	bad	0	bad	0.009	bad

Reverse pollination: Figure 6 shows that cross-pollination with "Coratina" produced the highest final fruit set comparing to self- and open pollination. This clearly indicates that "Coratina" is cross-compatible with "Khoderi". Self-pollination produced no fruit set which suggests that "Khoderi" is a self-incompatible cultivar.

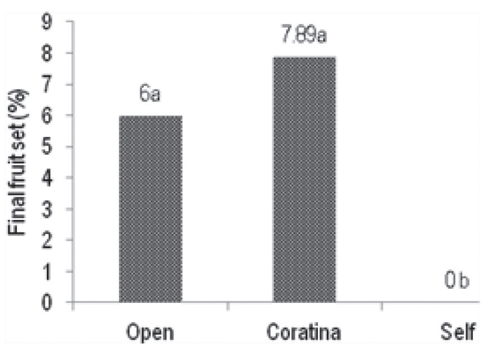

Figure 6. Final fruit set of „Khoderi" as affected by three types of pollination (open, cross-pollination with „Khoderi" and self-pollination). Fruit set from cross- and self-pollination are based on emasculated flowers
(*Different letters in the top of the columns indicated significant difference at p<0.05)

Discussion

In this paper we study the reproductive behavior of Italian olive Cultivar "Coratina" under Syrian coast conditions. Although pistil abortion was different between seasons, it was low and this may indicate that the most efficient factor that affects pistil abortion was the genetic background of the cultivar. Several factors have been reported to affect flower gender in olive such as climatic conditions, especially moisture and tree load in previous season (Koubouris et al., 2010). Generally, this low percentage of pistil abortion does not affect yield significantly. Lavee et al. (1996) found that the removal of 50% of the flowers in pre-bloom period of abundantly flowering shoots of olive did not affect fruit set or load. Pollen germination differed among years and cultivars especially between (2016-2019) compared to (2017-2018) and this seasonal differences could be due to the fact that pollens were cultured immediately in 2016 and 2019 but stored for several days in 2017 and 2018 seasons, also other factors could be responsible for these differences such as climatic conditions and pollen quantity produced by the tree (Ferri et al., 2008; Mazzeo et al., 2010). Mete et al. (2016) found significant difference in pollen germination of olive cvs. Hayat and Sari Ulak between study seasons.

In this study “Coratina” was self-incompatible under Syrian coast conditions, which is in accordance with (Camposeo et al., 2012). They reported that “Coratina” was self-incompatible in its main planting region in south Italy. Performance of the two pollinizers used in this study “Khodeiri” and “Dermlali” was relatively inconsistent but the overall results showed that both cultivars could pollinate “Coratina” flowers efficiently. Pollination efficiency showed to differ depending on year and area conditions, Selak et al. (2011) reported different final fruit set of “Oblica” olive when pollinated with “Leccino” depending on year and study site.

Meteorological data showed very unusual climatic conditions - especially temperature in 2018, the winter and spring were relatively warmer and rainfall continued until June which is unusual in the Mediterranean region, another factor that could affect fruit set was the previous year‘s yield. The 2017 season was characterized by high yield that might affect the available resources of “Coratina” trees.

ISI was used for most of the studies dealing with SI in olive and authors reported the usefulness of this index to evaluate SI in olive (Selak et al., 2011; Spinardi and Bassi, 2012), which is the same with fertility index (R) (Moutier, 2002; Mete et al., 2016). Our results showed some problems in those indices especially in the thresholds used for evaluation. Both indices are measured by dividing fruit set obtained by one type of pollination by fruit set obtained by cross or free pollination. Hence, the results will be relative and not consistent, not taking into account neither physiological nature nor commercial criterion of fruit set, for example, “Dermlali” was evaluated as bad pollinizer in 2017 but good at 2018 even though there were no significant differences in final fruit set between the two seasons, the only reason for this difference in evaluation was the low fruit set in open pollination in 2018 season comparing to 2017, hence, R index was high in 2018 and low in 2017. In 2018 season, in the same way, “Khodeiri” was evaluated as passable pollinizer and “Dermlali” as good pollinizer (better evaluation), but the data showed no significant difference between final fruit set obtained by pollinating “Coratina” with those two cultivars. Theoretically, if a pollinizer produced 0.5% as final fruit set, and 0.5% with open pollination (conditions like mono cultivar orchards or un-optimal conditions for fruit setting), this would be evaluated as good pollinizer (R= 1), but in field conditions this fruit set is not considered commercial. So, in our opinion, evaluating pollinizers according to only one criterion like R index would not be accurate and need to take into account the absolute values of final fruit set, rather than the relative value of R index, especially that both ISI and R indices are fluctuating depending on self-pollination, cross-pollination and open pollination and those three types of pollination do not follow the same tendency. Mostly self-pollination and cross-pollination with un-compatible cultivars produced less fruit set in unsuitable conditions, such as high temperature during olive bloom or short vernalization period but this was not shown to affect open pollination or cross-pollination with compatible pollinizers in the same severity (Ayerza and Sibbett, 2001; Lavee et al., 2002). Martin (1990) mentioned that a mature olive tree planted at density of 250 trees/ha would give 500000 flowers, most of those flowers abscise and only 1-2% are retained as fruits and that is enough to obtain commercial yield. According to this, we suggest a criterion to evaluate pollinizers according to flowering load and final fruit set as shown in Table 4. We use final fruit set because of high significant correlation between final fruit set and fruiting set at harvest and to overcome the problem of fruit drop not related to pollination which happens in summer and early fall mainly because of insects and weather conditions.

Table 4. Suggested evaluation of pollinizers depending on flowering load and final fruit set

Final fruit set (%)	Flowering load		
	Weak	Average	High
< 1%		bad	
1-2%	bad	acceptable	acceptable
> 2%	acceptable	good	good

In the same way evaluation of self- and cross-compatibility must be conducted in multi-cultivar orchards or germoplasm collections in order to ensure the presence of efficient pollinizers and to get the highest fruit set possible. According to data in Table 4 both “Khodeiri” and “Dermlali” would be considered to be good pollinizers for “Coratina” in both 2017 and 2018 seasons. We focused on “Khodeiri” as a pollinizer for “Coratina” because this cultivar is characterized by regular bearing which is not the case with “Dermlali” which is a biennial bearing cultivar.

Conclusion

Italian olive cultivar “Coratina” was self-incompatible under Syrian coast conditions with low percentage of pistil abortion, “Khodeiri” and “Dermlali” - the most common olive cultivars in Syrian coast, were efficient pollinizers for “Coratina”. It‘s suggested to plant “Coratina” in mixed orchards with “Khodeiri” because they are inter-compatible. Although “Dermlali” was an efficient pollinizer but the biennial bearing habit of this cultivar could limit the usefulness of it as pollinizer.

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