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Behaviour of some self-compatible almond selections in the Mediterranean south sea side (Morocco)

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SUMMARY – The almond selections evaluated had a late flowering period and low vigor. A loss of plant material at different stages of growth and development was observed. The trees had low branching and flowering was of poor quality during some years; which can be attributed to physiological and environmental effects. Expression of the self-compatibility trait, based on the rate of fruit set obtained in the absence of cross-pollination differed according to genotype, and differences were linked to the genetic background. The environmental effects on fruit set were important and showed variation between years. Production was not regular and yield obtained was low except for two selections: 'Lauranne' and (769x217)x16. Kernel size varied between selections and was generally small with an average of 1 g per nut. Similar results between selections in their behavior, reflects their genetic proximity with inbreeding effects.

Keys words: Self-compatibility, almond, expression, fruit set, environment.

RESUME *– "Comportement de certaines sélections autocompatibles d'amandiers sur la rive sud de la Méditerranée (Maroc)". Les sélections d'amandiers évaluées présentaient une période de floraison tardive et une faible vigueur. On a observé une perte de matériel végétal à différents stades de croissance et de développement. Les arbres avaient une faible branchaison et la floraison était médiocre pendant quelques années ; ce qui peut être attribué à des effets physiologiques et environnementaux. L'expression du caractère d'autocompatibilité, basé sur le taux de nouaison des fruits obtenus en absence de pollinisation croisée, a différé selon le génotype, les différences étant liées au fonds génétique. Les effets environnementaux de la nouaison des fruits ont été importants et subissaient une variation d'une année à l'autre. La production n'était pas régulière et le rendement obtenu était faible excepté pour deux sélections : 'Lauranne' et (769x217)x16. La taille de l'amandon variait selon les sélections et était généralement petite avec une moyenne de 1 g par fruit. Des résultats semblables entre sélections concernant leur comportement, reflètent leur proximité génétique avec des effets d'endogamie.*

Mots-clés : *Autocompatibilité, amandier, expression, nouaison du fruit, environnement.*

Introduction

Selection of self-fertile almond varieties is an appropriate tool to overcome pollination problems and to improve yield. A second generation of self-fertile varieties aims to enlarge the existing series with new selections like 'Antoñeta', 'Marta' (Egea and Dicenta, 1999), 'Blanquerna', 'Cambra' (Socias i Company *et al.*, 1999) and 'Mandaline' (Duval, 1999). These varieties result also from breeding with self-compatible almond genotypes. In the classic breeding program, self-compatibility could not be evaluated at the offspring level until 3 to 5 years after tree bearing. Complete expression of self-fertility in the orchard is complex and requires self-compatibility and autogamy (Weinbaum, 1985). Autogamy trait plays an important role in flower quality of self compatible cultivars (Godini *et al.*, 1992). The normal fruit set must be situated around 6% to admit their compatibility (Grasselly *et al.*, 1981; Socias i Company and Felipe, 1988).

Fruit sets carried by genotypes originated from Apulia (Italy) ecotype, were situated between 15 and 26% (Reina *et al.*, 1985). Godini *et al.* (1992) obtained 10.4% without hand pollination of nine genotypes for the same ecotype. This set was almost 42% when self-pollination was used and did not go beyond 18% when trees were isolated to prevent pollen transfer by insects. Elsewhere, Socias i

Company and Felipe (1992) obtained 11% of fruit set on 'Guara'. Torré-Grossa *et al.* (1994) obtained 20% with the variety 'Lauranne'.

Fruit sets obtained display a big variation according to plant material studied and climatic conditions. It permits to obtain a good yield even under unfavourable conditions of pollination. Adoption of self-compatible varieties became a running practice in many almond productive countries in the Mediterranean region. In Morocco, a tendency exists also to use self-compatible varieties to overcome pollination constraints, which frequently limits the yield in the traditional orchards. Evaluation of these new selections is necessary before their adoption. The purpose of this study was to evaluate the behavior of a collection of new self-compatible almond selections under Moroccan climatic conditions.

Materials and methods

Plant material and culture conditions

Plant material include seven foreign self-compatible almond selections (Table 1) planted at the INRA experimental station of Aïn Taoujdate. All genotypes have in their pedigree the parent 'Tuono', genitor of self-compatibility trait (Duval and Grasselly, 1994). Trees were grafted on 'Marcona' seedling which give homogeneous scion, planted on clay soil at 5x4m spacing in 1994. The orchard was irrigated with 2500 m^3/ha/year. It was managed following usual local procedures.

Table 1. Selections tested and their genetic origin

Selections	Genetic origin
'Guara'	Unknown
('Steliette' x 'Tuono') 293	'Steliette' x 'Tuono'
(769 x 217) x 16	'Ferralise' x 'Tuono'
(486 x 217) x 16	'Ferralise' x 'Tuono'
'Lauranne' 131	'Ferragnès' x 'Tuono'
'Steliette' 296	'Ferragnès' x 'Tuono'
'Steliette' 299	'Ferragnès' x 'Tuono'

Climatic conditions of the experimental site were characterized by an annual rainfall ranging from 350 to 400 mm and a chilling availability of 450 hours below 7.2°C.

Observations

Observations were carried out during 5 years and concerned vigor, spurs density, phenological stages, yield and pomological characteristics.

Vigor

Vigor was evaluated by the height of tree and circumference taken at 10 cm above the soil.

Spurs density

The number of spurs was recorded in two years (1999 and 2000) on 20 branches including the wood of two years old and taken randomly for each selection. Varieties were compared between them after reproductive spurs were converted to spurs density per linear meter (mL).

Phenological stages

Dates of fallen leaves were noted when 90% of leaves was abscised and those of full bloom were noted when 90% of bud were at E-F stage of Felipe (1977).

Flower abnormalities

For each selection a sample of 200 bud flowers at E stage of Felipe (1977) were taken randomly on the tree at full bloom stage. Flowers were separated on the basis of width ovary according to Socias i Company (1983, 1990) descriptions. Flower with very short pistils or atrophied were scored as sterile.

Self-compatibility

To evaluate self-compatibility, branches were bagged at balloon stage with cellophane, to prevent open pollination, after removing opened ones. Bags were removed 2 weeks later. Samples of five branches with 40 to 60 flowers per selection were selected on five trees and fruit sets were determined after June drop.

Yield and kernel characteristics

Pomological characterization was made on sample of 30 fruits taken yearly and randomly on each variety. Yield was also recorded.

All the data were analyzed statistically in order to compare selections between them.

Results

Vigor trees based on stem circumference varied between 21 cm for 'Steliette' x 'Tuono' 293 and 31 cm for 'Steliette' 296 with a average of 24 cm (Table 2). There is a highly significant effect between selections for the vigor. Trees had about 2.9 m of height of canopy and vigors index was very low in comparison with standard variety like 'Marcona'. Some tree loss occurred in this planting at different age.

Spurs density showed a significant difference between selections (Table 2). The average number of spurs varied between 20.5 for 'Guara' and 52.4 for ('Steliette' x 'Tuono') 293. The number of flower per shoot was correlated to spur density (r: 0.995) and show that all selections bear predominantly on spurs.

Table 2. Spurs density on the wood of two years and vigor of trees

Selections	Stem circumference (cm)	Canopy height (m)	Number of spurs per shoot of 1 mL	Number of flower per shoot of 1mL	Rate of dead trees
'Guara'	22.0	2.7	20.5	83	0.0
'Steliette'x'Tuono' 293	21.0	2.4	52.4	262	14.3
(769 x 217) x 16	23.8	2.8	41.2	211	0.0
(486 x 217) x 16	22.5	3.1	36.3	182	14.3
'Lauranne' 131	25.2	2.8	39.4	197	28.6
'Steliette' 296	31.3	3.6	27.1	136	0.0
'Steliette' 299	22.5	2.6	49.3	247	16.0
Average	24.04	2.86	38.0	188	
			21.1	22.7	
Level significance	0.193 (n.s.)	0.006 (**)	0.000(***)	0.000 (***)	

Level of significance: not significant (n.s.); significant at P = 0.1% (**) and P = 0.01% (***).
mL: Linear meter.

Phenological stages

The leaves started to fall in the second week of November and they abscised completely in the first week of January. This stage lasted for a period of 48 days and presented a variation between selections, which indicate their different sensitivity to environmental factors. It indicates the beginning of dormancy which was accomplished without particular symptoms of lack of chilling.

Flowering period for all selections was late and happened during the first week of March (Table 3). This stage lasted for 12 days and showed big variation between years. This variation appears to be linked to the climatic conditions particularly chilling and heat availability. Indeed, during the year 2000 where temperature was high enough, the flowering period was advanced 3 to 4 weeks and its duration was short, in comparison with those of 2003 when spring temperatures were low. A parallel response of all selections to variation climatic conditions was observed yearly.

Table 3. Dates of different phenological stages

Selections	Leaf fall		Flowering			
	Date	Duration (days)	Date FB	Far difference (days)		Average duration of flowering
				Before FB†	After FB†	
'Guara'	30/12	45	2/3	10	13	12
'Steliette'x'Tuono' 293	10/1	53	6/3	14	19	11
(769 x 217) x 6	10/1	51	28/2	8	12	14
(786 x 217) x 16	5/1	48	5/3	13	20	13
'Lauranne' 131	5/1	45	5/3	10	15	12
'Steliette' 296	30/12	50	5/3	11	20	11
'Steliette' 299	30/12	44	3/3	10	17	11
Average	4/1	48	4/3	11	17	12

†FB: Full bloom.

As indicated by small and abortive pistils, the flower sterility differed among selection and varied widely between 1 to 8% (Table 4). This observation was a general characteristic for each selection. Some years, it was difficult to identify the fertility type because the flowers were small.

Table 4. Percentage of single and twin by bud flower and rate of sterile flowers

Selections	Bud (%)		Sterile flowers(%)
	Single	Twin	
'Guara'	62	34	4
'Steliette' x 'Tuono' 293	41	58	1
(769 x 217) x 16	62	34	4
(486 x 217) x 16	92	3	5
'Lauranne' 131	83	9	8
'Steliette' 296	93	4	3
'Steliette' 299	53	46	1
Average	69.4	26.9	3.7

A different behavior of fruit set was observed between selections and their rate varied between 2 for 'Guara' and 23% for 'Lauranne'. The rate of fruit set was high enough to give a good yield and it was linked to flower density. Selections (769x217)x16, 'Lauranne' and 'Steliette' 299 give the best yield which was about 3 kg per tree (1.5 t/ha). During 5 years period the production was not regular and selections presented big variation. The precocity of bearing was observed at the 4th year except for 'Guara' that bore later (6th year). None of the selections had a regular production and an alternate bearing was observed.

Parameters relative to the kernel size, the weight and the thickness showed that fruit size varied between selections (Table 5) and was generally small. Average weight exceeded 1g per nut for only two selections (488x217x16 and 'Steliette' 296). It was about 1g or less for the others. Shelling percentage varied also between selections and was high (47%) for 'Steliette' and (486x217)x16. Shell was hard for the other selections.

Table 5. Yield and kernel pomological traits

Selections	Fruit set (%)	Average yield		Cracking percentage	Weight (g)		Nut size (mm)			Rate (%)	
		kg/tree	t/ha		Kernel	Nut	Length	Width	Thickness	Double	Shriveling
'Guara'	2.05	1.6	0.8	28.6	2.62	0.75	23.1	12.6	6.9	2.0	1.0
'Stel.'x'Tuono'	10.2	1.1	0.55	29.4	3.13	0.92	22.2	13.2	7.1	1.0	1.5
769x217)x16	19.1	3.0	1.5	32.2	3.38	1.09	22.4	13.7	7.6	0.0	1.0
486x217)x16	9.5	1.8	0.9	47.1	3.08	1.45	25.2	14.6	8.1	0.0	1.1
'Lauranne'	23.3	2.8	1.4	28.8	3.51	1.01	22.8	13.8	7.4	0.0	5.0
'Steliet.' 296	16.0	1.7	0.85	46.9	2.58	1.21	23.1	13.4	8.8	0.0	10.0
'Steliet.' 299	3.5	2.8	1.4	30.4	2.27	0.69	29.8	20.8	12.7	0.0	12.5

Percentage of double kernel was low (2%) for 2 selections and null for the others. The rate of defective kernel with abortive nut was characteristic of all selection and was high for 'Steliette' 299 and 'Steliette' 296 (10 to 12%), medium for 'Lauranne' (5%) and was low (1%) for the other selections . Some genetic and environmental causes are responsible for this defective kernel.

Discussion

The almond selections evaluated had late flowering period and are self-compatible. Their vigor was low with a loss of plant material at different stage of growth and development of trees, which had also a low branching. These traits were inherited from their parent 'Tuono' and were an important drawback of these selections. Poor flower quality is common also for all selections with variable level and difference in flower quality between years which may be attributed to physiological and environmental effects. But the similar results between selections reflect their genetic proximity. Indeed these selections show inbreeding depression (Socias i Company, 1990; Oukabli *et al*., 2003). Poor flower quality may result from inbreeding, which causes other effects such as reduction in vigor and fruit set. It causes also a loss in material at different stage.

This trait is unfavorable in the variety evaluation, especially a high level of blooming and high fruit set are required to obtain a good yield in this species. Yield and kernel size were medium with a small difference between selections.

Self-compatibility expression varied from year to year and between selections. This variability translates the strong environmental effect on the expression of this character, which is linked to selections genetic background. Similar results were reported with other plant material (Gradziel and Kester, 1999). The aptitude of selections to be self-pollinated is obtained and capacity of some selections like 'Lauranne', 'Steliette' 299 and (769x217)x17 to bear at medium level must be emphasized.

Selection for self-compatibility and late blooming predominated over other traits like kernel size, tree vigour and its branching. This later trait is particularly important when almond culture is scheduled for dry conditions and without irrigation. With self-compatibility, the yield is expected to be high, but in this case, it was low even when the environment conditions, particularly temperatures and honey bee pollination behavior, were favorable for pollination. Self-pollinating varieties will produce high sets in the cross-pollinated conditions (Oukabli *et al*., 2002).

Some abnormalities in behavior of these selections were emphasized, like poor flower quality, low vigor and branching, yield and reduced kernel size. These abnormalities could be linked to the inbreeding level of these selections. For the development of new self-compatible almond selections, breeding programmes must take into account these problems.

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