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SUMMARY – The blooming time of a total of 4173 seedlings derived from 118 controlled crosses, made at IRTA Mas Bové during the period 1975-1993, using 54 cultivars as parents, were analysed. As late blooming is a major aim of the breeding programme, in the main part of the crosses at least one of the two parents used was late or very late blooming, although, some crosses were also made between early and medium blooming cultivars. Offspring observations were carried out in different years between 1979 and 1997. To enable the joint analysis of data recorded in different years and, consequently, avoid as much as possible the influence on the blooming date of the annual climatology, 6 blooming groups were established (very early, early, early-medium, medium-late, late and very late) according to the average date recorded in the years (related as the number of days after 'Cavaliera', cultivar considered as reference by GREMPA) of a series of reference cultivars for each of the 6 established groups. The parents and the offsprings were included in these groups. The proportion of offsprings obtained was as follows: 1.4% very early, 10.8% early, 29.2% early-medium, 22.7% medium-late, 27.2% late and 8.7% very late. Important percentages of late or very late seedlings (superior as a whole to 60%) were only obtained in cross combinations where one parent was late or very late blooming and the other parent was medium-late, late or very late blooming.

Key words: Almond, breeding, progenies, blooming time.

RESUME – *"Date de la floraison dans des descendances de croisements d'amandier". Sur un total de 4173 arbres provenant de 118 croisements contrôlés, on a analysé la date de floraison en utilisant 54 géniteurs, réalisés au centre de Mas Bové durant la période 1975-1993. Etant donné que la floraison tardive est l'un des objectifs importants du programme d'amélioration, dans la plupart des croisements, au moins un des deux géniteurs utilisés était de floraison tardive ou très tardive. Toutefois, quelques croisements se sont réalisés entre des cultivars de floraison précoce ou moyenne. Les observations des descendances ont été prises sur différentes années, entre 1979 et 1997. Dans l'objectif de pouvoir analyser conjointement les données enregistrées sur différentes années et, par suite, éviter au possible l'influence de la climatologie sur la date de la floraison, on a établi 6 groupes de floraison (très précoce, précoce, précoce-moyenne, moyenne-tardive, tardive et très tardive) en accord avec la date moyenne enregistrée durant ces années (en relation avec le nombre de jours après 'Cavaliera', cultivar considéré comme référence dans le GREMPA) d'un ensemble de variétés de référence pour chacun des groupes considérés. Les parentaux et les descendants ont été inclus dans ces groupes. La proportion de descendants obtenue était la suivante: 1,4% très précoce, 10,8% précoce, 29,2% précoce-moyenne, 22,7% moyenne-tardive, 27,2% tardive et 8,7% très tardive. D'importants pourcentages ont été obtenus seulement d'individus tardifs et très tardifs (supérieur dans l'ensemble à 60%) dans les combinaisons où l'un des deux géniteurs était de floraison tardive ou très tardive et l'autre de floraison moyenne-tardive, tardive ou très tardive.*

Mots-clés : *Amandier, amélioration génétique, croisements, date de floraison.*

Introduction

Blooming time is a very important feature in almond. It is one of the earliest fruit species to bloom in the winter or early spring and crop production is often seriously damaged by late frosts or reduced by poor pollination and fertilization during cool, cloudy or rainy weather. In inland areas of the Mediterranean region, the occurrence of spring frosts is common (Grasselly, 1990). The probability of crop losses decreases as the season progresses, because the risk of spring frost is more reduced and also temperatures are usually higher and more favourable for the processes of pollination and fertilization. Therefore, late blooming is a desirable trait and has been an aim of most almond cultivar breeding programmes (Kester and Asay, 1975; Grasselly and Crossa-Raynaud, 1980; Romero and Vargas, 1992; Kester and Gradziel, 1996; Monastra and Raparella, 1997).

Blooming date may change from year to year, according to the weather before and during bloom. However, the flowering sequence of different cultivars is relatively constant over the years and

blooming scales have been developed with the aim to classify the cultivars regardless of the year. Small variations in the flowering order may occur from year to year, due to differences in the chilling and heat requirements of the cultivars (Socias i Company, 1999).

Blooming time is considered as a quantitative trait. Most of the results on the transmission of blooming time show that this trait is inherited quantitatively (Grasselly, 1972; Vargas *et al*., 1984; Dicenta *et al*., 1993; Kester and Gradziel, 1996). However, Kester (1965) observed a bimodal distribution in progenies derived of the late blooming budsport of 'Nonpareil', 'Tardy Nonpareil', which suggest that a single dominant gene could be involved in the blooming date. This presence of a single dominant gene in 'Tardy Nonpareil' and its transmission was confirmed later (Grasselly and Olivier, 1985; Socias i Company *et al*., 1998). Thus, blooming time seems to be determined by a major gene and by modifier genes inherited quantitatively (Socias i Company, 1997).

In 1975, an almond cultivar breeding programme was started at IRTA Mas Bové. Late blooming is a very important trait for this programme and the crosses were planned regarding this aim since the start (Vargas and Romero, 1984, 1988; Vargas *et al*., 1984, 1998). In this paper an analysis was made considering the results obtained from a number of crosses. With the aim to compare blooming dates in progenies observed in different years, parents and seedlings were classified according to a scale considering blooming dates of a number of cultivars during different years in Mas Bové.

Materials and methods

The blooming time of 4173 seedlings, derived from 118 controlled crosses, made at IRTA Mas Bové during the period 1975-1993, using 54 cultivars as parents, were analysed.

As late blooming is a major aim of the breeding programme, in all crosses at least one of the two parents showed medium-late, late or very late blooming time. In addition, a few crosses made for pollination studies between early and medium blooming cultivars were also included in this analysis. 'Tardy Nonpareil' was not used as parent and no bimodal distribution was observed in any progeny.

Offspring observations were carried out in different years between 1979 and 1997. The full blooming date was recorded as the number of days after 'Cavaliera' flowering time, which is the cultivar considered as reference by GREMPA (Grasselly and Crossa-Raynaud, 1980).

To enable the joint analysis of data recorded in different years and thus to reduce the influence of the annual climatology on the blooming date, 6 blooming groups were established (very early, early, early-medium, medium-late, late and very late) according with the average date recorded in these years (related as the number of days after 'Cavaliera') of a series of reference cultivars for each of the 6 established groups. The reference cultivars for the 6 groups are included on Table 1.

Table 1. Blooming groups

Group	Blooming time	Reference cultivars
1	Very early	'Avola', 'Cavaliera', 'Común B', 'Desmayo Largueta' and 'Ramillete'
2	Early	'Abundancia', 'Atocha', 'Belardino', 'Carriset', 'Chimatera', 'Colorada', 'Desmayo Rojo', 'Esperanza Forta', 'Garrigues', 'Mas Regany', 'Mollar de la Princesa', 'Mollar de Tarragona', 'Peraleja', 'Planeta Elche' and 'Princess'
3	Early-medium	'150-Z-4', 'Ardechoise', 'Bruantine', 'Comun A', 'Gabaix', 'Marcona', 'Nonpareil' and 'Rof'
4	Medium-late	'854', 'Cristomorto', 'Filippo Ceo', 'Genco', 'Miagkoskorlupyi', 'Picantilli' and 'Rana'
5	Late	'Ferraduel', 'Ferragnes', 'Glorieta', 'Masbovera', 'Primorskyi'†, 'Tardive de la Verdiere', 'Tardy Nonpareil'†, 'Tarragones', 'Texas' and 'Tuono'
6	Very late	'Garbi' and 'Yaltinskyi'

†For the yearly separation between groups 5 and 6, in group 5 only the flowering period of the cultivars 'Tardy Nonpareil' and 'Primorskyi' are considered.

The intervals of the 6 groups in different years were calculated according to the following formula:

$$\frac{\overline{X}_{i-1} + \overline{X}_i}{2} \leq \text{Group i} > \frac{\overline{X}_i + \overline{X}_{i+1}}{2}$$

where: $\overline{X}_i$ = average date of the reference cultivars for the Group i in the corresponding year.

Exceptionally, for the yearly separation between groups 5 and 6, in group 5 only the flowering time of 'Tardy Nonpareil' and 'Primorskyi' were considered, with the aim to include in group 6 only the cultivars or seedlings actually outstanding in very late flowering.

In Table 2 the intervals used for the classification in different groups and years analysed are presented. The parents and the offspring were included in these 6 blooming groups.

Table 2. Intervals used for the classification of the seedlings according with their full blooming dates (related as the number of days after 'Cavaliera')

Year	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
1979	<4	4-7	8-16	15-20	21-25	≥26
1980	<7	7-10	11-16	17-20	21-27	≥28
1981	<9	9-15	16-22	23-26	27-32	≥33
1982	<13	13-23	24-33	34-41	42-50	≥51
1983	<9	9-19	20-26	27-31	32-37	≥38
1984	<8	8-14	15-23	24-35	36-48	≥49
1985	<6	6-11	12-17	18-23	24-28	≥29
1986	<7	7-14	15-19	20-24	25-29	≥30
1987	<11	11-17	18-23	24-29	30-33	≥34
1988	<5	5-11	12-16	17-21	22-29	≥30
1989	<5	5-9	10-13	14-18	19-24	≥25
1990	<9	9-15	16-21	22-27	28-32	≥33
1991	<2	2-6	7-13	14-18	19-21	≥22
1995	<7	7-11	12-16	17-21	22-26	≥27
1996	<12	12-20	21-29	30-39	40-47	≥48
1997	<11	11-16	17-22	23-26	27-32	≥33

In Table 3 the cross groups, the number of crosses and the number of seedlings derived from these crosses are shown.

Results and discussion

The results are given in Tables 4 and 5. As expected, the results clearly show a quantitative transmission of the blooming time.

The proportion of offspring obtained was as follows: 1.4% very early, 10.8% early, 29.2% early-medium, 22.7% medium-late, 27.2% late and 8.7% very late.

Important percentages of seedlings (more than 60% as a whole) of late or very late blooming seedlings, aim of the cultivar breeding programme, were only obtained in cross combinations where one parent was late or very late blooming and the other parent was medium-late, late or very late blooming.

Conclusion

Important percentages of late or very late blooming cultivars were only obtained in cross combinations where one parent was late or very late blooming and the other parent was medium-late, late or very late blooming.

Table 3. Cross groups (female × male or vice versa)

Cross groups	No. of crosses	No. of seedlings
1 × 1	3	17
2 × 2	1	5
3 × 1	1	24
3 × 2	2	18
3 × 3	1	8
4 × 1	13	430
4 × 2	3	97
4 × 3	8	507
5 × 1	8	673
5 × 2	3	78
5 × 3	10	635
5 × 4	16	535
5 × 5	26	793
6 × 1	1	10
6 × 3	6	122
6 × 4	1	12
6 × 5	10	150
6 × 6	5	59
Total	118	4173

Table 4. Seedling classification by blooming groups (%)

Cross groups	No. of seedlings	Classification of the seedlings (%)					
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
1 × 1	17	82.4	5.9	5.9	5.9	0	0
2 × 2	5	0	80.0	0	20.0	0	0
3 × 1	24	54.2	25.0	16.7	4.2	0	0
3 × 2	18	33.3	22.2	33.3	11.1	0	0
3 × 3	8	0	50.0	12.5	37.5	0	0
4 × 1	430	1.4	36.7	47.7	10.5	2.8	0.9
4 × 2	97	10.3	32.0	27.8	25.8	3.1	1.0
4 × 3	507	0	14.6	61.7	15.0	7.7	1.0
5 × 1	673	0.9	17.1	49.6	23.3	7.9	1.2
5 × 2	78	1.3	20.5	29.5	30.8	10.3	7.7
5 × 3	635	0.3	6.1	38.1	35.3	18.6	1.6
5 × 4	535	0	0	6.2	27.1	42.6	24.1
5 × 5	793	0	0	1.5	17.2	61.9	19.4
6 × 1	10	0	0	40.0	60.0	0	0
6 × 3	122	0	0	9.8	47.5	39.3	3.3
6 × 4	12	0	0	0	8.3	66.7	25.0
6 × 5	150	0	0	0	22.0	58.7	19.3
6 × 6	59	0	0	1.7	13.6	67.8	16.9
Total	4173	81.4	10.8	29.2	22.7	27.2	8.7

Table 5. Seedling classification by blooming groups (%)

Crosses†	No. of seedlings	Classification of the seedlings (%)					
		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
2	17	82.4	5.9	5.9	5.9	0	0
4	29	44.8	34.5	13.8	6.9	0	0
5	448	2.7	36.2	47.1	10.5	2.7	0.9
6	778	2.1	19.3	46.5	23.8	7.2	1.2
7	595	0.2	15.1	57.1	17.8	7.9	1.8
8	635	0.3	6.1	38.1	35.3	18.6	1.6
9	657	0	0	6.8	30.9	42.0	20.2
10	805	0	0	1.5	17.0	62.0	19.5
11	150	0	0	0	22.0	58.7	19.3
12	59	0	0	1.7	13.6	67.8	16.9
Total	4173	1.4	10.8	29.2	22.7	27.2	8.7

†Female parent group + male parent group.

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