PHENOLOGICAL PHASES OF *ARGANIA SPINOSA* (L. SKEELS) FLOWER

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ABSTRACT

Argan (*Argania spinosa*) flowering was observed and flower phenological phases were described at Ait Melloul and Argana, two sites southwest of Morocco. Inflorescence of argan is initiated on annual shoots, on last growth season shoots as well as on mature wood. It is a glomerule, a cymose clusters of up to 15 pentamerous flowers. Flowering potential for the season is reached before initiation of flower phase development. Then, the uppermost flower of a glomerule develops to bloom first followed by outer ones. Flower phenological phases are progressively flower bud BF (1 to 2 mm), flower bud with an emerging style BFS (1 to 2 mm), blooming flower FE (2 to 3.15 mm), dry flower with a corolla FSCP (2 to 3.15 mm) and finally dry flower with no corolla FSC (1 to 2 mm). Phases BFS and FE are at their population maximum for only twenty days (late March to mid April at Ait Melloul, mid April to early May at Argana). Because at these phases, stigmas and pollen from different sources are available, that would correspond to maximum within-population gene flow. Beginning May, flowers of a glomerule start to drop off individually until exhaustion of the stock. Large significant variability is observed between trees at a site for flowering and for phenological phases importance.

Key words: *Argania spinosa*, argan, flowering, phenological phases

INTRODUCTION

Understanding flower biology, which is closely dependant on floral structure, phenology and pollen flow, allows a better comprehension of the diversity dispersal pattern of plant species. It also facilitates plant pollination system determination, controlled mating and hybridization.

Argan (*Argania spinosa* (L. Skeels)) a perennial tree endemic to Morocco occurs mainly along the south west coast between north of Safi and south of Sidi Ifni (BAEHNI 1948; EHRIG 1974; PRENDERGAST & WALKER 1992). Main flowering season takes place during spring, even if variability is observed between populations and between trees of a population (PERROT 1907; METRO 1952; RIEUF 1962; MONTOYA 1984; FERRADOUS *et al.* 1996; BANI-AAMEUR *et al.* 1998).

Argan is a monoecious species which flowers occur single or grouped in inflorescence of glomerule type on the axils of the leaves of shoots or the nodes of mature wood (PERROT 1907; FERRADOUS *et al.* 1996). The flowers are small, hermaphroditic (PERROT 1907; BAEHNI 1948; SAUVAGE & VINDT 1952; BOUDY 1952; BIONDI 1981). The calyx is formed of five pubescent white round sepals located between two brown bracts. The corolla formed of five light yellow petals is cup-like. At the base of the petals are attached five anthers each on a long filament and five short staminodes. The style is short and conical. The ovary is superior, hairy and formed of two to four loculi.

Recent research on argan genetics and diversity (MSANDA *et al.* 1994; BANI-AAMEUR & HILU 1995; EL MOUSADIK & PETIT 1996; ZAHIDI *et al.* 1996; FERRADOUS *et al.* 1997; ZAHIDI 1997) raised concern about the lack of documented scientific information on argan flowering and fruiting. The objective of this study is to describe the external development of argan flower emphasizing the distribution of phenological phases.

MATERIALS AND METHODS

Observation sites are Ait Melloul (AM) in the Souss plain and Argana (AR) on southern slopes of High Atlas Mountains, south west of Morocco. It is an arid region of Mediterranean climate where rain concentrates in the winter (EMBERGER 1925; LE HOUEROU 1989; FERRADOUS *et al.* 1996).

A preliminary investigation concerned flower morphological phases. The shapes encountered were described through visual examination and discrete classes were set as shown in figure 1. Flower bulk samples were size-screened using Afnor screens of variable apertures (1mm, 2mm, 3.15mm and 5mm). Data was recorded on 30 random trees at each site every 20 days between February and August 1994, making sure to: 1) cover spring period, often reported as the main flowering season and 2) focus on

flower phenological phases description and evolution. For each tree, two branches to the north and two to the south were sampled randomly at 1.5 m height and the first annual shoot of each branch was labelled for glomerule counts (GC). Shoot lengths which were not significantly different, varied from 1.2 to 4.2 cm. Flower counts (FC) were made on the first three glomerules of a labelled shoot to the north. Observations were supported by photographs of glomerules and flowers at various phases.

Analysis of variance was performed on GC using a three-factor design on an orthogonal sample of two sites, 30 trees per site and nine dates. The four shoots per tree were used as repeats. For the analysis of variance of FC, phenological phase was set as the fourth factor and glomerules as the repeats. This analysis concerned 24 trees per site because some trees did not flower. The factor tree was hierarchical to the factor site because the trees were not repeated between sites, (STEEL & TORRIE 1960; DAGNELI 1984; MONTGOMERY 1984). The Least Significant Difference test (LSD)(a = 5%) of equality of means was used to compare significant factors means. Statistix (Analytical Software) software was used for computation.

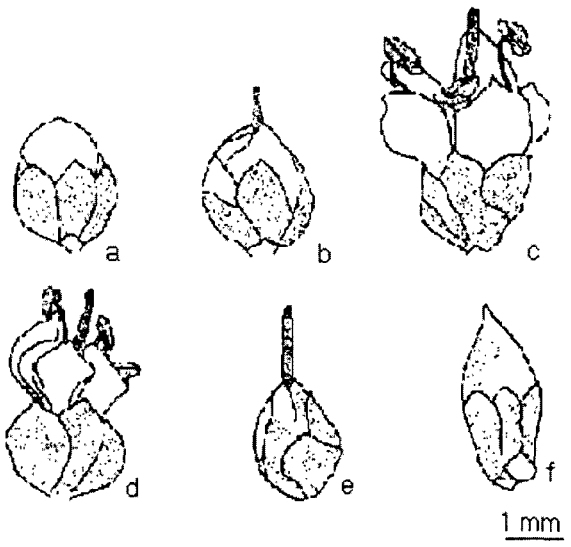

Figure 1. Description of flower phases of *Argania spinosa*: **a**. BF **b**. BFS **c**. FE **d**. FSCP **e**. FSC, and **f**. A newly formed fruit for comparison.

RESULTS AND DISCUSSION

Phenological phases

Argan flowers occurred in the axils of the leaves or at the nodes of annual shoots, on last growth season shoots as well as on mature wood. They are grouped in cymose clusters, or glomerules, where the uppermost flower develop to bloom first followed progressively by outer ones (Fig. 2a, 2b & 2d). The evolution of a flower happens through a sequence of five phenological stages denominated BF, BFS, FE, FSCP and FSC (Fig.1 & 2).

BF – The perianth flower bud completely enclosed in protective green scales is visible. Its size varied between one and two mm through swelling and elongation (Fig. 1a & 2b)

BFS – Emergency of the stigma of the bud at the early stages and of part of the style, which elongates out of the flower bud still enclosed in protective green scales (Fig. 1b, 2c & 2d). Therefor the stigma is available for foreign pollen. Similar to BF, its size varied between one and two mm.

FE – The flower show distinct (Fig. 1c, 2d & 2e). It's is larger than previous stages (2 to 3.2 mm). It is pentamerous. The calyx of a flower is formed of five pubescent greenish round sepals. The corolla is a whitish cup like of five curved petals. Each one of the five stamens is located almost opposite to a petal. The anthers are attached to filaments that are longer than the style. The five anthers are dehiscent extrorsely by means of longitudinal slits making pollen available for dispersal. The style is simple, erect greenish. The stigma is green, conical and inconspicuous.

FSCP – Corolla and androecium become tarnished yellowish brown (Fig. 1d). Size is similar to the previous stage. This phase marks the limit to pollen dispersal. The style is still erect but we notice some color change toward the brown. This phase may also set the limit for stigma receptivity.

FSC – Loss of corolla and androecium (Fig. 1e & 2f). The ovary to which the style is still attached is superior. Its outer wall is heavily covered with hairs and the color is turning to greenish brown. Size is one to two mm.

Distribution of phenological phases

Dates, site, trees within a site and their interactions were highly significant for glomerule count on annual shoots (GC) (Table 1), whereas site, dates and phases were highly significant for flower count (FC) (Table 2). But in this case, site interactions with phases, dates or both were not significant for FC. Therefor importance of phases was not particularly emphasized at a site, a date or at a site for a particular date.

Ait Melloul (average 7.8 and maximum 22.2) showed more than twice as many glomerules as Argana (average 3.0 and maximum 24.0). An identical site ranking was observed for FC (Fig. 4).

The first three dates were not significantly different for GC or FC showing that population flowering potential for the season was established earlier, before initiation of flower phase development when we started recording data (Fig. 3 & Table 3). The observed GC and FC plateau between March and mid May also suggests that spring is the main flowering season as it was previously reported

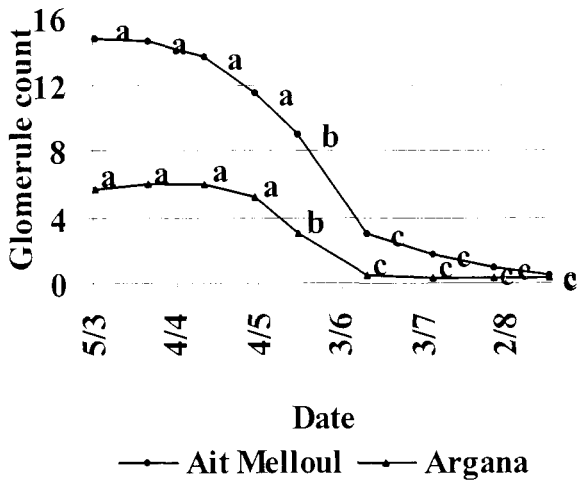

Figure 3. Mean glomerule count per date. Values are the mean of four shoots and thirty trees at each date at Ait Melloul (AM) and Argana (AR). Different letters note significant differences (LSD, a = 0.05) as comparisons were made between means of dates.

Table 1. Analysis of variance of glomerule count.

Source	DF	Mean square
Site	1	12184 **
Tree / site	58	192.6 **
Dates	8	4637.6 **
Date × site	8	756.6 **
Datex tree / site	464	20.4 **
Error	1620	9.0

DF: degrees of freedom, **: significant at $\alpha = 0.01$.

Table 2. Analysis of variance of flower per glomerule count.

Source	DF	Mean square
Site	1	151.9 **
Tree / site	46	7.1 ns
Dates	5	121.8 **
Date × site	4	16.6 ns
Phase	4	265.7 **
Phase × site	5	38.1 ns
Phase × date	20	112.1 ns
Phase × date × site	20	15.7 ns
Phase × tree / site	184	5.6 **
Phase × date × tree / site	920	2.92 **
Error	2880	0.5

DF: degrees of freedom, **: significant at $\alpha = 0.01$, ns: non-significant.

(PERROT 1907; METRO 1952; MONTOYA 1984; FERRADOUS *et al.* 1996; BANI-AAMEUR *et al.* 1998). Beginning May, flowers composing a glomerule and glomerules began to drop off, though with more intensity at Ait Melloul than at Argana (Fig 3 & Fig 4). Note that the glomerule did not drop off as a solid structure. Instead, its components were lost individually until exhaustion of glomerule flower stock.

Phase BF was the most important and BFS was the least important, even if differences between BFS, FE, FSCP and FSC were not significant (Table 3). At the beginning (early March), the glomerule is almost entirely formed of BF flowers (Fig. 4). Progressively and at different pastes, each one of these would follow the succession of phenological phases through BFS, FE, FSCP and finally FSC before to drop off or to form a fruit following pollination. Except that BFS did not seem to be a required step in argan flower development, since it was not observed for eight trees at Ait Melloul and two at Argana. Note that at BFS, the stigma, if receptive, may be a target for cross-pollination. Thus, the extent of this phenomenon at this stage of development may vary between trees. Anyway, anthesis occurs between BF and BFS (BELMOUDEN & BANI-AAMEUR 1995). There for, self-pollination may occur before stigma emergence. However more research is needed to determine the relative extent of cross- or self-pollination in Argan. Note that phases BFS and FE were at their population maximum for only twenty days (late March to mid April at Ait Melloul, mid April to early May at Argana). Then, because stigmas are supposedly at maximum receptivity and pollen from different sources is available for dispersal, this period would correspond to maximum within-population gene flow. Although argan reproductive mode is not fully understood and still need more detailed research. But, even if observations of one year at only two sites are insufficient for the establishment of a pattern, this work would facilitate further experiments because argan flower phenological phases are now determined.

Significant variability was recorded between trees for GC (Table 1). At the extremes, a tree at AM and five at AR did not flower, whereas two trees at AM and one at AR formed as many as 24 glomerules per shoot. Remarkable difference was also observed between flowering periods of individual trees. Hence the observed plateau of spring GC population mean masked a variable flowering behavior of trees. Early trees were attaining their flowering potential while new glomerules were still being formed by shoots of late trees (16 trees at AM and 10 trees at AR).

Individual tree effect (tree / site) was not significant for FC, suggesting that argan trees did not differ for mean flower count per phase per glomerule (Table 2). However, the interaction with phase (phase × tree / site) or with phase and date (phase × date × tree / site) were highly

Table 3. Mean phase and date flower count per glomerule of populations of *Argania spinosa* from two sites, Ait Melloul and Argana..

Dates	Phases					Total	Mean
	BF	BFS	FE	FSCP	FSC		
March 5	4.75	0.08	0.21	0.06	0.01	5.11	1.02 a
March 23	2.95	0.60	0.56	0.54	0.47	5.12	1.02 a
April 14	1.10	0.49	0.85	0.71	1.13	4.28	0.86 ab
May 3	0.39	0.14	0.41	0.90	0.88	2.72	0.54 bc
May 18	0.23	0.00	0.07	0.38	0.47	1.15	0.23 cd
June 12	0.15	0.00	0.00	0.06	0.11	0.32	0.06 d
Mean	1.60 a	0.22 b	0.35 b	0.44 b	0.51 b	3.12	0.62

Different letters note significant differences (LSD, $\alpha = .05$) as comparisons were made between means of dates and phases.

Table 4. Mean, maximum and coefficient of variation (CV %) of flower count per glomerule per phase of *Argania spinosa* populations at two sites.

Site		Phases				
		BF	BFS	FE	FSCP	FSC
Ait Melloul	Mean	2.08	0.16	0.39	0.64	0.78
	Maximum	15.3	4.0	5.7	9.3	6.7
	CV %	49.8	244.9	162.8	113.1	108.0
Argana	Mean	1.11	0.28	0.30	0.24	0.24
	Maximum	7.3	4.0	4.0	3.0	2.7
	CV %	56.3	185.8	148.2	116.7	221.9

Minimum values are zero, CV: maximum CV value of dates, Maximum: values corresponded to different trees.

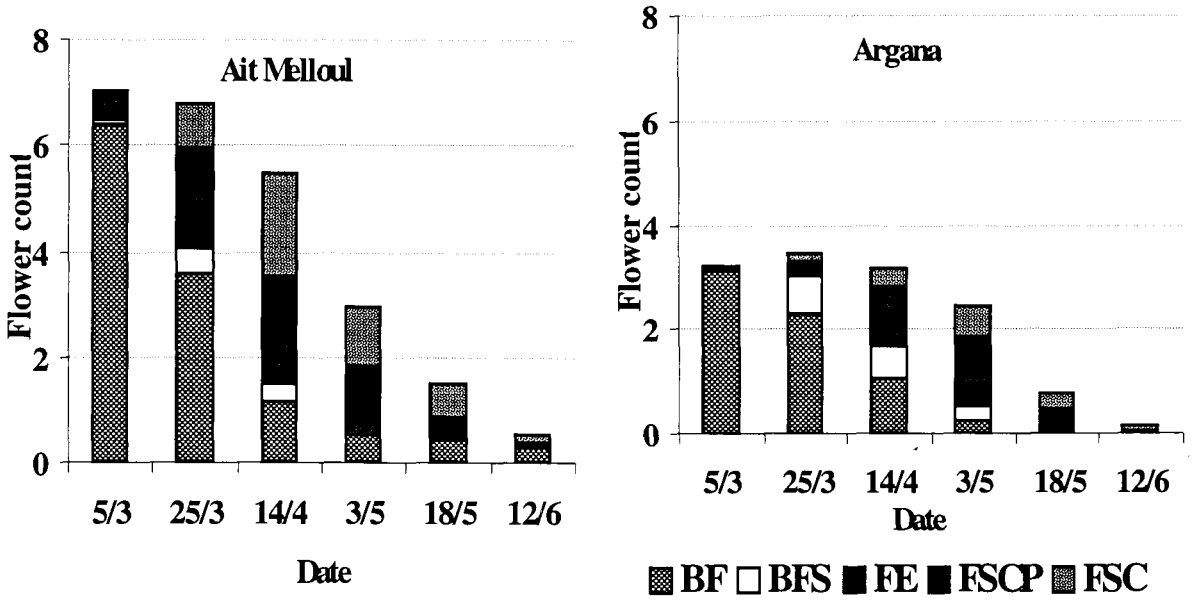

Fig. 4. Mean flower count per glomerule per phase and date at two *Argania spinosa* populations, Ait Melloul and Argana. Values are the means of three glomerules and 24 trees.

significant. The great variability that was observed between trees for each phase or for phases at a particular sampling date was stressed by remarkable values of maximum FC and its coefficients of variation (Table 4). Because these values identified different trees for different dates, flowering period extent observed in figure 4 probably masked large variability between trees of a site. This was previously encountered with fruit set of argan trees (BANI-AAMEUR *et al.* 1998). In that study, some trees set fruits once a year in March (early trees) or in June (late trees); others set fruits twice, in March and in June illustrating a complex breeding behavior

This study is a first step toward a better understan-ding of argan flowering and pollination, which are still largely undetermined. We had the opportunity to quantify flowering using glomerule counts as well as flower in glomerule counts. External development phases of argan flower as well as their time distribution are now available to contribute to enhance argan flowering and pollination database. However more detailed research is needed to fully understand argan reproductive mode for a better comprehension of argan diversity dispersal pattern or realization of controlled hybridization.

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