Pinus halepensis - Pinus brutia french comparative provenance tests

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Summary

Pinus halepensis and *Pinus brutia* provenances (and progeny) trials were planted in South eastern France in order to evaluate genetic diversity within and among species. Two plantations were settled in 1976 and 1978 within the FAO/SCM/CRFM/4bis project. More recently 5 new plantations, mainly with *P. brutia* provenances were settled in 1996 and 1997 within the MPC and FORADAPT European project. Variability of growth and survival was analyzed.

Introduction

Pinus halepensis Mill. (Aleppo pine) and *P. brutia* Ten. (Brutia pine or Turkish red pine) play a major role in low elevation Mediterranean forests, covering around 7 millions ha in the western and eastern part of the Mediterranean Basin. Due to their good adaptation to dry summer conditions and their ability to rapidly colonized abandoned lands from agriculture or burned areas, these species not only constitute ecologically valuable natural stands but also permits afforestation in dry conditions for production or protection purposes. In 2000, Schiller reviewed the inter- and intra-specific genetic diversity of these Mediterranean pine species. Diversity among species and provenances within species was generally assessed by morphological markers (seeds, cotyledons, needles…) or biochemical traits (terpenes, isozymes, DNA markers). The genetic diversity of adaptive traits (survival, growth, drought or frost tolerance..) or of shape and branch characteristics was more rarely reported.
We present here a short synthesis of the French field experiments were these two species were planted. The manuscript is mainly based on previous reports of European or national projects.

Material and Method

✔ *The ''Old'' P. halepensis P. brutia* provenance tests

A two-site comparative trial with provenances of the *halepensis-brutia* complex were planted in south-eastern France in 1976 (Ceyreste plantation) and 1978 (Vitrolles plantation) within the international FAO trial (FAO/SCM/CRFM/4bis). Names and origins of the 27 provenances tested in this trial (12 *P. halepensis* provenances, 12 *P.brutia* provenances and 3 *P.eldarica* provenances) are given in Table 1.

Table 1 : List of the *Pinus* provenances tested in Vitrolles and Ceyreste plantations

species	FAO code	provenance	country	Lat.	Long.	Elev.	site	species	FAO code	provenance	country	Lat.	Lon.	Elev.	site
P. halep.	A2	Elea	Greece	37°46	21°32	200	C, V	P. brutia	B1	Chania	Greece	23°57	35°17	850	C,V
P. halep.	A4	Chalkidique	Greece	40°11	23°21	125	C, V	P. brutia	B3	Lassithiou	Greece	25°32	35°06	1100	C,V
P. halep.	A8	Sakiet Sidiyoussef	Tunisia	36°15	8°25	700	C, V	P. brutia	B4	Alexandropolis	Greece	26°13	41°08	200	C,V
P. halep.	A12	Zaouia Ifrane	Morocco	33°15	-5°23	1250	C, V	P. brutia	B6	Marmaris	Turkey	28°18	37°00	175	C,V
P. halep.	A14	Ouardane Bouksane	Morocco	35°03	-5°08	900	C, V	P. brutia	B7	Isparta	Turkey	29°32	38°04	1043	C,V
P. halep.	A16	Soportujar	Spain	37°10	-3°15	800	C, V	P. brutia	B8	Düzlerçani	Turkey	30°25	37°03	250	C,V
P. halep.	A19	Cehegin	Spain	38°05	-1°55	850	C, V	P. brutia	B9	Pamuçak	Turkey	30°41	37°40	780	C,V
P. halep.	A21	Serra	Spain	39°50	-0°28	600	C, V	P. brutia	B10	Bozburun	Turkey	30°45	37°21	520	C,V
P. halep.	A23	Tarrasa	Spain	41°28	2°06	250	C, V	P. brutia	B11	Bakara	Turkey	32°43	36°09	300	C,V
P. halep.	A24	Gemenos	France	43°25	5°40	150	C, V	P. brutia	B12	Silifke	Turkey	33°43	36°13	100	C,V
P. halep.	A26	Otricoli	Italy	42°24	12°32	400	C, V	P. brutia	B13	Camgölü	Turkey	35°20	41°50	70	C,V
P. halep.	A27	Vico del Gargano	Italy	41°54	16°00	225	C, V	P. brutia	B14	Baspinar	Turkey	35°15	37°48	700	C
								P. brutia	B15	Kisildag	Turkey	35°58	36°21	370	C,V

*** C : Ceyreste ; V : Vitrolles**

The main characteristics of the 2 plantations are the followings:

	Ceyreste (1976)	**Vitrolles** (1978)
nb prov per block	5	6
nb trees per unit plot	20 (2rows x 10 trees)	8
total nb trees (surface)	3300 (1,2 ha)	2500 (1,9 ha)
nb of prov.	12 PH + 13 PB + 3 PE	12 PH + 12 PB
elevation	470 m	200 m
longitude (gr E)	3.71	3.26
latitude (gr N)	48.40	48.32
soil	sandstone	limestone
rainfall	790 mm	570 mm

In summer 2004 the Vitrolles plantation was destroyed by a forest fire.
Variability of survival and total height was analyzed using respectively a generalized linear model and a linear model (ANOVA) respectively. Prior to ANOVA, height growth was adjusted to environmental effects (mainly soil conditions) with an spatial approach (Iterated Papadakis method).

✔ *The ''new'' P. brutia* provenance tests

In order to evaluate provenance variability of *P. brutia* in less dry conditions (deeper soils or higher elevation) than those of the ''old" provenances plantations, a ''new'' five-site comparative trials was settled within the Mediterranean Pine and Cedar (MPC) European project and the FORADAPT INCO project (Table 2). These plantations share some provenances with tests established, in the same project, by Moroccan and Tunisian partners.
18 *Pinus brutia* provenances and 3 *P. halepensis* as control were tested (Table 3). Seven other *P.brutia* provenances evaluated by the French forest service were also included in Bousquet d'Orb and Naucadery plantations. The experimental plantations consist of randomized incomplete blocks, 30 trees per block (15 prov. x 2 trees).
Survival and total height were analyzed using a generalized linear model and a linear model (ANOVA) respectively.

Table 2 : list of the ''new'' *P.brutia* provenance plantations

site	Year plant.	altitude	Surface (ha)	soil	Number of Prov
Bousquet d'Orb	F 1995	580	2	limestone	28
Naucadery (Laure)	S 1996	150	1.5	limestone	27
Toulourenc forest	F 1996	600	2	limestone	22
Bedoin forest	S 1997	600	2	limestone	25

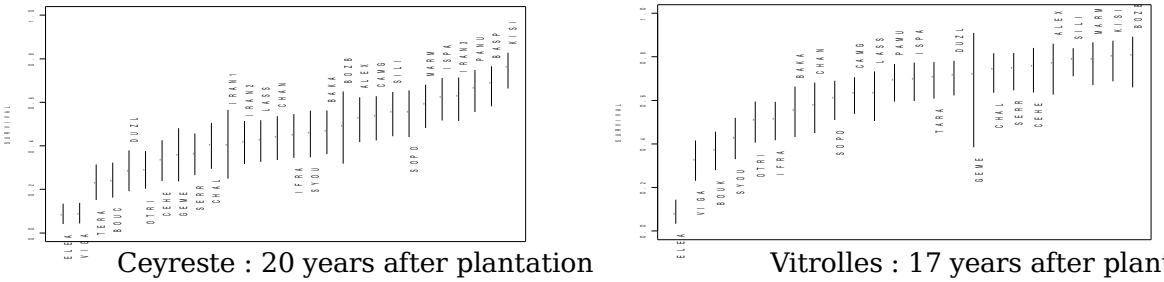
Table 3 : list of the provenances tested in the ''new'' 5-site trial

Species	provenance	country	Species	provenance	country
P. brutia	050 Karsanti	Turkey	*P. brutia*	120 Karabucak	Turkey
P. brutia	071 Kiyra	Turkey	*P. brutia*	121 Güzelcluk	Turkey
P. brutia	073 Suçati	Turkey	*P. brutia*	122 Bigadic	Turkey
P. brutia	076 Guzelbag	Turkey	*P. brutia*	124 Camkonagi	Turkey
P. brutia	079 Pinargözü	Turkey	*P. brutia*	125 Göktepe	Turkey
P. brutia	100 Karadag	Turkey	*P. brutia*	129 Koças	Turkey
P. brutia	109 Gökçesu	Turkey			
P. brutia	110 Findikpinari	Turkey	*P. halepensis*	001 St Etienne du Grès	France
P. brutia	113 Melli	Turkey	*P. halepensis*	002 Port-Cros	France
P. brutia	114 Merkez	Turkey	*P. halepensis*	003 Mejjou	Morocco
P. brutia	115 Karaçay	Turkey	*P.halepensis*	011 Vilmorin	France
P. brutia	116 Eskibag	Turkey	*P. halepensis*	015 Gémenos	France

Result

✔ *The ''Old'' P. halepensis P. brutia* provenance tests

Present analysis of survival and growth of twenty years old trees, completes preliminary results published in 1992 (Bariteau).
Survival rates were significantly different among provenances (Figure 1). In both sites (Ceyreste and Vitrolles), the highest mortality rates were observed for some *P. halepensis* provenances from Greece (Elea), Italy (Vico del Gargano and Otricoli) and Morocco (Ouardane Bouksane). Provenances from France, Spain and north-eastern Greece exhibited high survival rates, but no clear geographic pattern was observed. The highest survival rates were observed for some *Pinus brutia* provenances specially those originating from eastern Taurus (Kisildag and Baspinar).



Ceyreste : 20 years after plantation Vitrolles : 17 years after plantation

Figure 1: Survival rate (ordinate) of *Pinus* provenances (up : *P. brutia* and down : *P. halepensis)*

The analysis of growth revealed significant differences between *Pinus* species and provenances. At Vitrolles (dry site on compact limestone), best growing provenances belong to *P. halepensis*. In this plantation, provenances originating from high elevation stands exhibited a low growth. At Ceyreste, on sandstone, most of *P. brutia* provenances grew faster than *P. halepensis* provenances.

Comparison of provenance growth between the 2 sites, shows a clear species x site interaction (figure 2). However provenance ranking within species remains almost stable. This important result confirms that *Pinus halepensis* and *Pinus brutia* have different ecological optima. The best growing *P. brutia* provenance was Marmaris followed by Kisildag and Silifke from eastern Taurus.

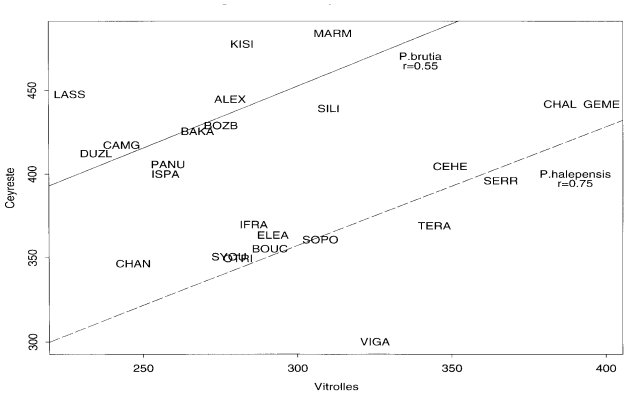


Figure 2: Comparison of *P. halepensis* and *P. brutia* provenance growth (cm) at Ceyreste and Vitrolles.

✔ *The "new" P. brutia* provenance tests

SURVIVAL

One of the 5 plantations (Toulourenc) was seriously damaged by a severe frost that occurred in December 1996 and January 1997. Analysis of mortality revealed significant difference among provenances. Provenance mortality varied from 53% (Mersin Findikpinari, *P.brutia*) to nearly 100% (Mejjou, *P. halepensis,* from Morocco). Among *P. brutia* provenances, tolerance to frost seems to be correlated to altitude and longitude of provenance origin. Provenances from higher elevation sites and from Eastern Taurus Mountain were less damaged.

Survival was recorded at the end of the 1998 growing season in the 4 other sites. In order to estimate the impact of the unusually hot (and dry) climatic conditions of year 2003, mortality was also recorded in 2004 for 2 plantations (Bousquet d'Orb and Naucadery). In Bedoin and Laquina plantations, the Moroccan *P. halepensis* provenance "Mejjou" originating from the Atlas Mountain exhibited the highest mortality level (22% and 17% respectively). In all other provenances, 1998 mortality did not exceed 14% in Bedoin and 9% in Laquina. In Bousquet d'Orb plantation, mortality was higher for the 3 *Pinus halepensis* provenances used as control (16% for the 2 French provenances and 46% for "Mejjou") than for *Pinus brutia* provenances (12%). No significant differences were observed among *Pinus brutia* provenances. Finally, in Naucadery plantation mortality was very low (3% in 2004) without significant differences among provenances. Climatic conditions of year 2003 did not affect survival of the pines. Only 7 trees, all in Bousquet d'Orb plantation but from 7 different provenances, would have been killed by the heat and drought stress.

GROWTH

Total tree height was measured in 1998 at Bousquet d'Orb and in 2004 at Bousquet d'Orb and Naucadery. Tree growth was significantly affected by the site of plantation, species and provenance origin. French Aleppo pine provenances grew faster than *P. brutia* pines (Figure 3) except for the acidic soil conditions of the Laquina plantation. The Moroccan

“Mejjou” provenance exhibited a limited growth. Within *P. brutia*, the site x provenance interaction was moderate as compared to the effect of the 2 main factors (Figure 4). Growth at Bousquet d’Orb is negatively correlated (r = -0,63) to the elevation of the stand where seeds were collected. The 5 best performing provenances are the following: Mersin-Findikpinari (east Taurus), Antalya, and 3 provenances from north-western part of *P. brutia* range: M.K.Pasa-Camkonagi, Orhaneli-Göktepe from Turkey and Alexandropolis from Greece.

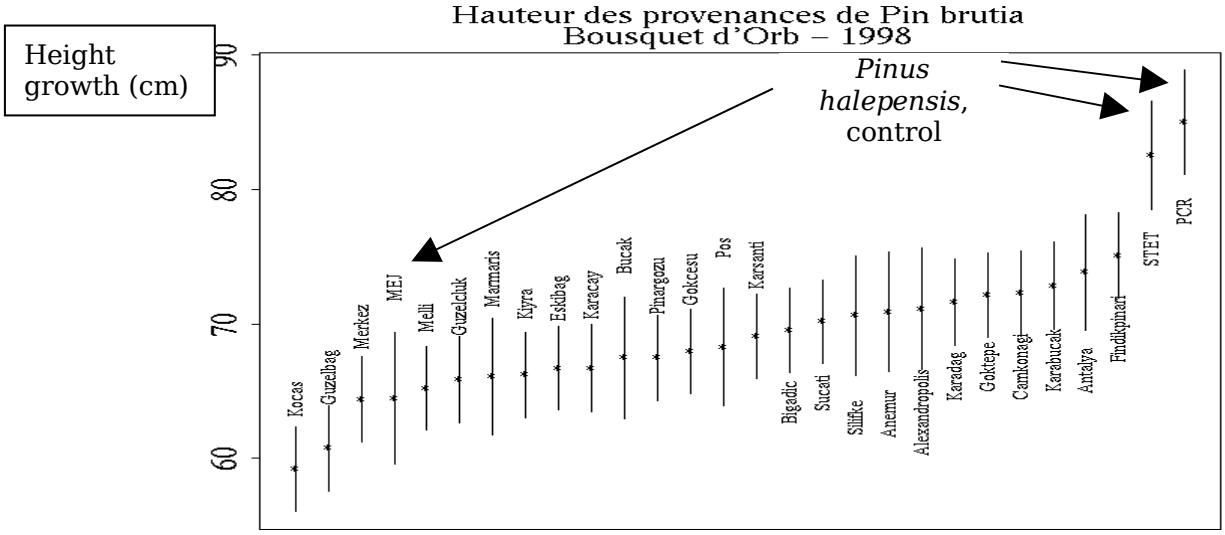


Figure 3 : comparison of growth among 3 years old *Pinus brutia* provenances (Bousquet d’Orb Plantation

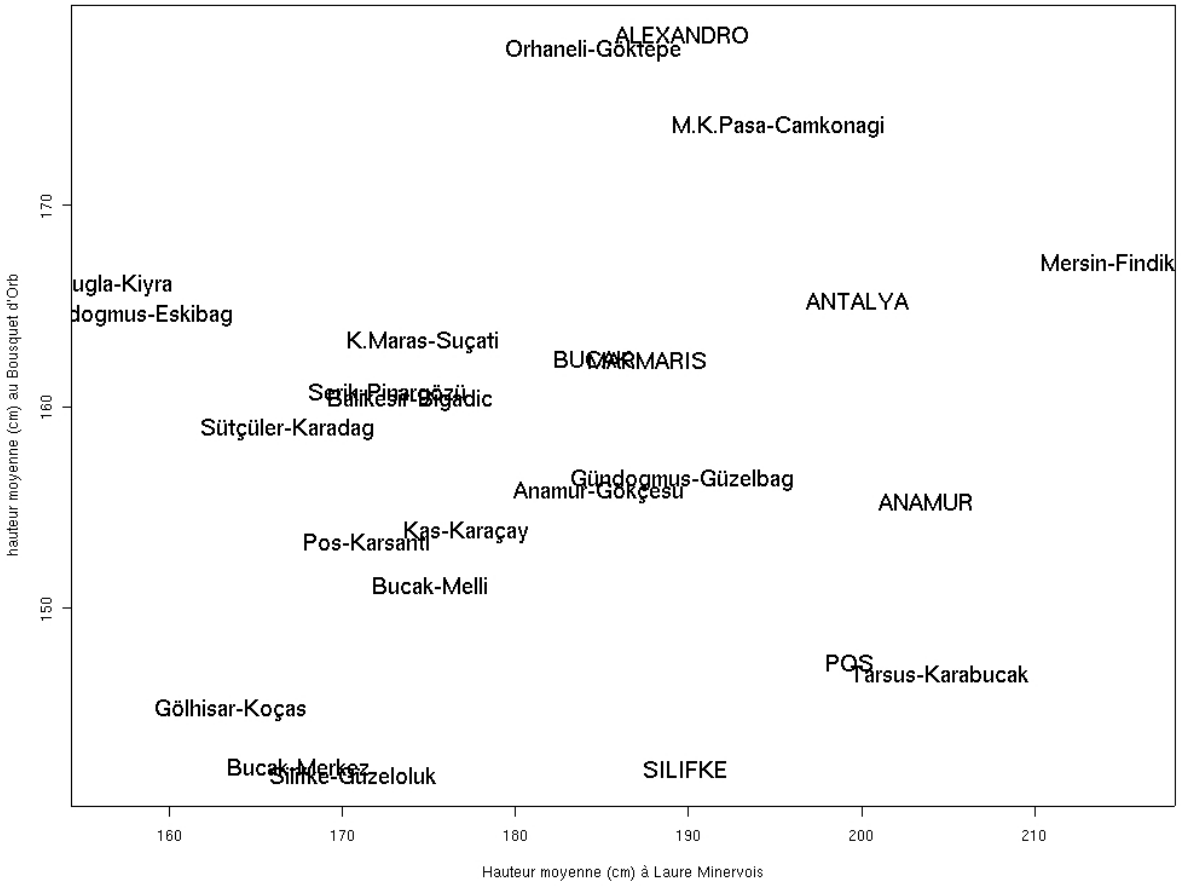


Figure 4: Comparison of *P. brutia* provenance growth (cm) at Bousquet d’Orb and Naucadery

Conclusion and perspectives

P. halepensis is the more drought tolerant Mediterranean pine tree and its environmental and economical importance will undoubtedly increase in the “Earth warming” context. Due to its efficient natural regeneration and colonisation of abandoned land from agriculture, *P. halepensis* is today rarely artificially planted in southern France. However, we recommend to use local seed sources for any new plantations. These provenances are frost resistance and exhibit good growth.

Objective of the new multisite *Pinus brutia* provenance test was to estimate the variability of adaptive traits in less hot and dry conditions than those of the 2 previous provenance trials (1976 and 1978, Ceyreste and Vitrolles).The preliminary results confirm the better adaptation of this species to frost as compared to *Pinus halepensis*. The high susceptibility to frost of the Moroccan *P. halepensis* provenance use as control also confirms the risk of introducing exotic Aleppo pine provenances in Southern France. In 1985, artificial pine forests settled in southern France with Italian seed sources were also seriously damaged by frost.
In the new comparative test, French *P. halepensis* provenances grow faster than *P. brutia* provenances which confirms the highest juvenile growth of *P. halepensis*. When become older, *P. brutia* trees are expected to grow faster and best provenances should overpass *P. halepensis* as observed at Ceyreste plantation.
Pinus brutia is undoubtedly a good alternative species for afforestation in southern France, at middle elevation (400-700 m) which generally correspond to the upper limit of *P. halepensis* and the lower limit of *Pinus nigra.* First analysis of growth variability among *P. brutia* provenances indicate good performances of material originating from middle altitude eastern Taurus mountain, such as “Mersin Findikpinari” or from north-western part of *P. brutia* natural area. Provenances from eastern Taurus would also exhibit a high survival rate and a good stem straightness (Figure 5).

Figure 5 : Main characteristics of *P. brutia* provenances tested by FR1/AVIGNON (in the old (*) and new (o) tests)