Nursery Factors Influencing Containerized *Pinus pinaster* Seedlings' Initial Growth

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Maritime pine (*Pinus pinaster*) containerized seedlings were raised outdoors at different fertilizer regimes, sowing date or culture duration to assess nursery factors influencing first year growth in the field. Seedling biomass, and N, P and K content before outplanting were affected by these different factors but the one year field growth was more related to N concentration than with morphological traits.

The results are discussed in view to improve the plant stock quality in nursery.

Key words Maritime pine, fertilization, nitrogen, nursery, growth, sowing date, planting date
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1 Introduction

Since 10 years, the production of genetically improved seeds of Maritime pine (*Pinus pinaster*) is strongly increasing, from open pollinated seed orchards, and more recently from controlled pollinated seed orchards. In order to fully profit of last research improvements, sylviculturists tend to abandon traditional way of afforestation by direct sowing with unimproved seeds to the benefit of afforestation by plantation of seedlings of the more recent varieties: 25 millions of containerized Maritime pine seedlings from seed orchards are produced each year in France. Since there is no production models up to date, nursery breeding standards are required in order to produce top quality seedlings and to ensure rapid initial field growth (Fraysse and Crémière, 1994).

Several studies describing the influence of seedling quality on the growth after planting have shown that the mineral status of seedlings is often related with field performances: growth performance of newly planted seedlings can be improved by fertilization practices in the nursery to counter unfavourable soil nutrient conditions at the plantation site, particularly with spruce and Douglas fir bareroot stock (Smith et al. 1966, Mullin and Bowdery 1977, Van den Driessche 1980, Burdett et al. 1984) and spruce containerised stock (Munson and Timmer 1989 a, b, 1990, 1991, Timmer and Munson 1991). Concerning pine species, attemps to regulate growth rate by an exponential nutrient supply were not successful on Scots pine, but shoot to root ratio was influenced by the fertilization regime (Troeng and Achzell 1988). Foliar nitrogen content was positively correlated with Loblolly pine early field growth (Larsen et al. 1988) and late season nursery fertilization with nitrogen affected field growth rate on Ponderosa pine (Gleason et al. 1990) and longleaf pine (Hinesley and Maki 1980).

In this study, the initial field growth of different Maritime pine containerized seedlings representative of the commercial nursery productions, is examined with a particular attention to the effects of:

– different nutritional regimes (Sivaillan trial),
– culture duration for a same planting date (Barp trial 1),
– planting season related to container type, for one sowing date (Barp trial 2).

2 Materials and Methods

The plant material consisted of one-year-old containerized Maritime pine seedlings. Seeds were collected from an open seedling seed orchard located at Sore (44°20'N, 0°35'W, altitude 30 m) on a sandy soil in the Landes area (France). Seeds were stratified at 4°C for 7 weeks, sown and grown outdoors in a commercial nursery (Forelite) in the southwestern France (45°02'N, 0°50'W, altitude 30 m).

2.1 Sivaillan Trial

Seedling Culture and Measurement of Seedling Attributes

Seeds were sown outdoors on early June 1994 and grown in plastic containers (Forelite-Stamp, France) raised from soil on paletts with 551 seedlings per square meter and an individual container volume of 82 cm^3. The containers were filled with a mix of peat and fine pine-bark (40/60, V/V). Sample of commercial seedling lots reared under various fertilization regimes were compared:

R1: 3.5 kg Nutricote 16-10-10 (NPK) 8–9 months per substrate cubic meter, total amount 55 mg N seedling^{-1},
R2: 3,5 kg Osmocote 18-11-10 (NPK) 8–9 months per substrate cubic meter, total amount 62 mg N seedling^{-1},
R3: 4 kg Floranid 15-9-15 (NPK) 8–9 months per substrate cubic meter, total amount 59 mg N seedling^{-1},
R4: Fertilization irrigation application. For each watering, a constant nutrient solution was used (N=100, P=10, K=33) with 120 mg N l^{-1}, total amount 22 mg N seedling^{-1},
R5: 0,5 kg Osmocote 18-6-12 (NPK) 3–4 months per substrate cubic meter and fertilization application (idem R4) total amount 31 mg N seedling^{-1}.

The first three regimes (R1, R2 and R3) correspond to three commercial slow-release fertilizers incorporated with substrate when containers were filled. For R4, no solid fertilizer was added in substrate, nutrient solution was applied through each irrigation during growing phase. Before planting (December 1994), 116 seedlings were sampled for each treatment. A first sub-sampling of 36 seedlings was measured for morphological parameters: shoot height, basal diameter, shoot and root dry mass (oven-dried at 65°C for 12 h) and nutrient status. N, P and K concentrations were analysed on total dry mass for each sample.

Outplanting Trial and Field Measurements

The second sub-sampling of 80 seedlings was planted near the nursery on a sandy soil, all vegetation was moved prior to planting, site was fully ploughed and competing vegetation that grew after planting was treated with an herbicide. The outplanting trial was a randomized complete block design, with four replicates, testing the five nursery fertilizer treatments, the experimental unit was 20 sample trees. Subsequent height growth for the first year after outplanting was measured in November 1995.

2.2 Barp – Trial 1

Seedling Culture and Measurement of Seedling Attributes

Seedlings were grown in the same containers and in the same substrates that have been previously described. Four samples of commercial seedling lots sown at different dates and grown under fertilization regime R2 described above, were compared:

T1: Sowing on January 3
T2: Sowing on May 3
T3: Sowing on June 1
T4: Sowing on July 8

Seedling attributes were measured before planting (November 1994) in the same way than for Sivaillan trial.

Outplanting Trial and Field Measurements

The planting site is located in the Landes area (44°38'N, 0°46'W, altitude 20 m) on a sandy soil. The sampling, the site preparation, the experimental design and the field measurements were the same as Sivaillan trial.

2.3 Barp – Trial 2

Seedling Culture and Measurement of Seedling Attributes

The first seedling lot was sown on June 30 (fertilization regime R5). Seedlings were grown in plastic containers (PC) and outdoor overwinter stored. The second seedling lot corresponded to the traditionnal Maritime pine stock production. Seedlings were germinated and grown outdoor on peat blocks (PB) placed in a plastic tray directly on the ground, with 250 seedlings per square meter and an individual container volume of 200 cm^3. Seedlings were sown on the same date as plastic container lot, and reared under fertilization regime R2. On early November a sample of 464 seedlings for each containers was obtained. Peat blocks were root pruned on the bottom, trays were raised from soil on paletts and overwinter stored outdoors in the same conditions as plastic containers, without any more fertilization. Every two months, from November to May for each container, a sample of seedlings was planted on field site. Before each planting date, the same sampling and measurements were made as in previous trials.

Outplanting Trial and Field Measurements

The planting site is the same as Barp 1 trial and site preparation was realised in the same way. The outplanting trial was a full factorial experiment testing four planting dates (November, January, March and May) for the two seedling lots in a randomised complete block design with four replicates. The experimental unit was 20 sample trees. For each date and each container, 80 seedlings were outplanted. Subsequent height increment for the first year was recorded between outplanting and November 1995 when growth stopped for all treatments.

3 Results

3.1 Sivaillan Trial

Nursery Phase

Fertilizer treatments in the nursery had a great impact on Maritime pine seedlings morphology, particularly biomass production, and on nutrient status (Table 1).

Relative analysis (Timmer and Armstrong 1987, Haase and Rose 1995) distinguish the effects of fertilization regimes on seedling growth and N status (Fig. 1).

For the three fertilization regimes (R1, R2 and R3) with slow release fertilizers, the results are very similar for biomass production and N uptake. For R4 and R5, the total dry mass production was significantly ($P < 0,05$) lower than for the slow release fertilizers (R1, R2 and R3). In the same time N concentration was lower, consequently N uptake decreased.

Table 1. Response of Maritime pine seedlings to five fertilizer treatments applied in a commercial nursery. Seedlings morphology and nutrient status (% total dry mass) before outplanting. Data collected just before planting from a sample of 36 seedlings per treatment.

Fertilizer regime at the nursery	Shoot height (cm)		Total dry mass (mg)		N	P	K	S/R ratio (1) (mg/mg)		H/D ratio (2) (cm/mm)	
	Mean(4)	*e*% (3)	Mean	*e*%	(%)	(%)	(%)	Mean	*e*%	Mean	*e*%
R1	18.8 a	*4.6*	1483 a	*13.3*	1.44	0.12	0.96	2.4	*9.3*	9.6	*9.0*
R2	17.2 b	*4.6*	1322 ab	*11.8*	1.55	0.32	0.81	2.4	*7.3*	9.9	*6.7*
R3	15.7 c	*6.4*	1257 b	*13.9*	1.41	0.17	0.85	2.2	*10.6*	9.0	*6.6*
R4	11.8 d	*4.3*	753 c	*9.3*	1.11	0.17	0.93	2.4	*9.8*	8.6	*3.5*
R5	12.9 e	*5.5*	867 c	*15.6*	1.16	0.16	0.88	2.6	*8.5*	8.8	*7.3*

(1) S/R = Shoot mass/root mass (ovendry mass 65°C, 12 hours)
(2) H/D = Shoot height/basal diameter
(3) *e*% = confidence limits in %, *e*% = 100 [(s t/√n)/m] at p = 0,05
(4) Similar letters represent no statistically significant differences among fertilizer treatments (p < 0,05) according to Student's test

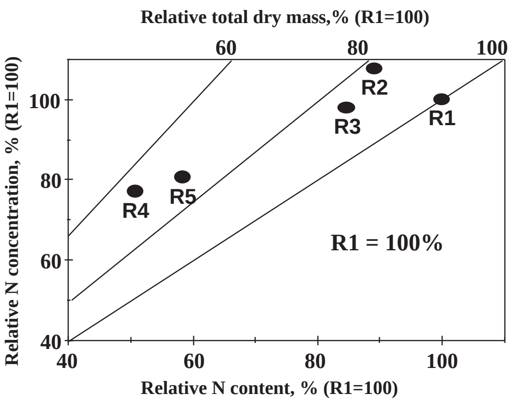

Fig. 1. Relative responses for total dry mass, N content and N concentration of Maritime pine containerized seedlings sown on June for five fertilization regimes in the nursery (R1: 55 mg N seedling^{-1}, R2: 62 mg N seedling^{-1} , R3: 59 mg N seedling^{-1}, R4: 22 mg N seedling^{-1}, R5: 31 mg N seedling^{-1}). Seedling attributes were measured before planting in December.

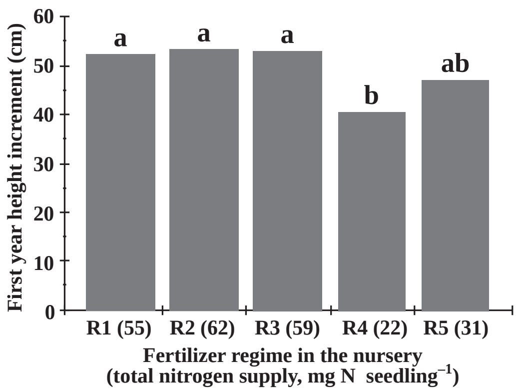

Fig. 2. Effect of fertilizer treatments applied in the nursery on subsequent height increment for the first year after outplanting. Similar letters represent no statistically differences among fertilizer treatments (p < 0,05) according to Tukey's studentized range test.

Outplanting Performance

For all the treatments no mortality was registred. The seedlings that received the fertilization regime R4 in nursery grew less (P < 0,05) (Fig. 2). They were also the smallest before planting. The highest first year growth was associated with increased N concentration and N uptake in seedlings before planting, but it is difficult to distinguish whether the response is attributable to differences in preplant seedling size or to the building of plant nutrient reserves particularly for nitrogen. There was no clear effect of the seedlings shoot to root ratio on the first year height growth.

Table 2. Effect of culture duration according to four different sowing dates for containerized Maritime pine seedlings in a commercial nursery. Seedling morphology and nutrient status (% total dry mass), data collected just before planting from a sample of 36 seedlings per treatment.

Treatment	Sowing date	Shoot height (cm)		Total dry mass (mg)		N	P	K	S/R ratio (1) (mg/mg)		H/D ratio (2) (cm/mm)	
		Mean(4)	*e*% (3)	Mean	*e*%	(%)	(%)	(%)	Mean	*e*%	Mean	*e*%
T1	Jan 3	44.0 a	*2.4*	5408 a	*7.4*	0.8	0.2	0.6	3.6	*7.7*	13.0	*5.3*
T2	May 3	25.2 b	*4.1*	1930 b	*13.7*	1.2	0.2	0.8	2.5	*5.6*	10.6	*4.8*
T3	June 1	23.0 c	*7.6*	1811 b	*15.5*	1.1	0.2	0.7	2.8	*10.1*	10.0	*8.6*
T4	July 7	14.5 e	*4.6*	903 d	*11.2*	1.7	0.3	1.3	2.7	*8.1*	9.2	*6.8*

(1) S/R = Shoot mass/root mass (ovendry mass 65°C, 12 hours)
(2) H/D = Shoot height/basal diameter
(3) *e*% = Confident limits in %, *e*% = 100 [(s t/√n)/m] at p = 0,05
(4) Similar letters represent no statistically significant differences among fertilizer treatments (p < 0,05) according to Student's test

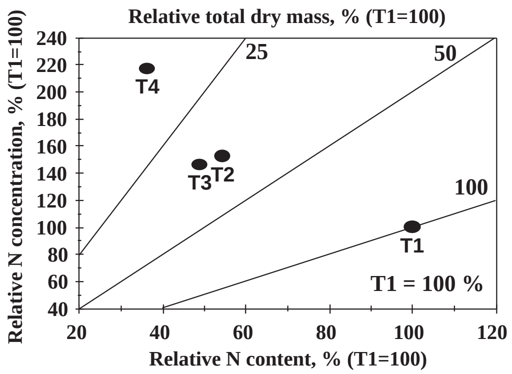

Fig. 3. Relative responses for total dry mass, N content and N concentration of four Maritime pine seedling lots sown in January (T1), May (T2), June (T3) and July (T4). Seedling attributes were measured before planting in November.

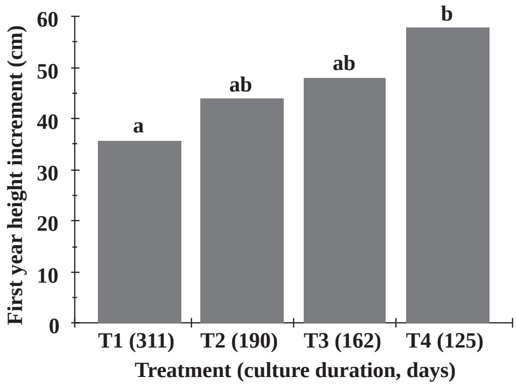

Fig. 4. Subsequent height increment for the first year after outplanting of four Maritime pine seedling lots sown in January (T1), May (T2), June (T3) and July (T4). Height was measured one year after planting in November.

3.2 Barp – Trial 1

Nursery Phase

Culture duration on the nursery had an evident effect on morphological traits for Maritime pine containerized seedlings (Table 2).

Relative responses are analysed in Fig. 3, the seedlings from January (T1) were the largest ones and presented in the same time the highest relative N content and the lowest N relative concentration due to very high growth dilution effects. The youngest and consequently the smallest seedling lot (T4) had in the same time the highest level for N concentration, however N content was very similar with treatments T2 and T3.

Outplanting Performance

For all the treatments, no mortality was observed. The best performance was obtained with the youngest seedlings (T4); they had a continuous and vigourous growth during the growing season (Fig. 4). Those seedlings that were the small-

Table 3. Effect of culture duration in outdoor storage according to four planting dates for two containerized Maritime pine seedling lots sown at the same date in a commercial nursery. Seedling morphology and nutrient status (% total dry mass) before outplanting. Data were collected from a sample of 36 seedlings per treatment.

Planting date	Container	Shoot height (cm)		Total dry mass (mg)		N	P	K	S/R ratio (1) (mg/mg)		H/D ratio (2) (cm/mm)	
		Mean(4)	*e*% (3)	Mean	*e*%	(%)	(%)	(%)	Mean	*e*%	Mean	*e*%
Nov	(5) PC	15.6 a	*4.1*	1025 a	*13.6*	1.11	0.21	1.14	3.2	*8.8*	9.0	*5.9*
Jan	"	15.2 a	*3.9*	1270 b	*11.4*	1.03	0.18	1.00	1.9	*9.5*	8.2	*5.9*
Mar	"	17.3 b	*3.4*	1535 c	*11.3*	0.80	0.10	0.56	2.0	*9.8*	8.1	*6.0*
May	"	19.1 c	*3.0*	1994 d	*9.6*	0.84	0.19	0.54	2.6	*7.1*	7.3	*6.2*
Nov	(6) PB	19.9 cd	*6.0*	1643 cd	*12.0*	1.57	0.19	1.00	7.6	*7.7*	8.5	*6.9*
Jan	"	20.3 d	*4.1*	1856 cd	*12.1*	1.60	0.23	1.02	6.7	*5.6*	8.1	*6.0*
March	"	22.7 e	*5.3*	2784 e	*13.7*	1.23	0.15	0.67	7.5	*10.1*	7.9	*5.7*
May	"	31.3 f	*5.7*	4344 f	*10.6*	1.01	0.14	0.61	5.0	*8.3*	8.2	*4.9*

(1) S/R = Shoot mass/root mass (ovendry mass 65°C, 12 hours)
(2) H/D = Shoot height/basal diameter
(3) *e*% = Confident limits in %, $e\% = 100\ [(s\ t/\sqrt{n})/m]$ at p = 0,05
(4) Similar letters represent no statistically significant differences among fertilizer treatments (p < 0,05) according to Student's test
(5) PC = Plastic Containers (82 cm^3)
(6) PB = Peat Blocks (200 cm^3)

est before planting had a poor relative N content but the highest N concentration level (Fig. 3). There is a clear relation between culture duration, seedling size, N concentration and growth.

3.3 Barp – Trial 2

Nursery Phase

The outdoor overwinter storage duration had parallel effects on seedlings morphology and nutrient status, for the two kinds of container seedlings (Table 3).

Growth development and biomass accumulation increased during winter and early spring, particularly for the peat block seedlings which had the largest container size (Table 3). Similar response was found for Loblolly pine (Perry 1971) and for Sitka spruce (Bradbury and Malcom 1978, Timmer et al. 1991). There was a large shoot/root ratio difference between the two container types, higher for peat blocks because of large spacing, but very little difference within container type for various sampling dates. No difference or very little differences were noted on shoot height to basal diameter ratio between containers or sampling dates.

Internal N and K concentrations declined very fast all along the season for both container seedling lots since no effect was observed for phosphorus present at the lowest level (Table 3). This decrease in N and K concentration is natural and mainly due to wood accumulation overtime and also nutrient leaching by winter and early spring rains. Similar observations have previously been reported for containerized Black spruce seedlings (Timmer et al. 1991).

For each planting date, N concentration, total dry mass an consequently N content were systematically higher for the peat block seedling lot (Fig. 5).

In the same time, no difference or very little differences were found for P and K concentration between the two seedling lots (Table 3).

Outplanting Performance

We noted similar trends for the two types of container seedlings: the planting dates had an evident and significant effect on the first year height growth between outplanting date and height measurement in November 1995 (F = 96.86; Pr > F = 0.001) (Fig. 6). Better growth is

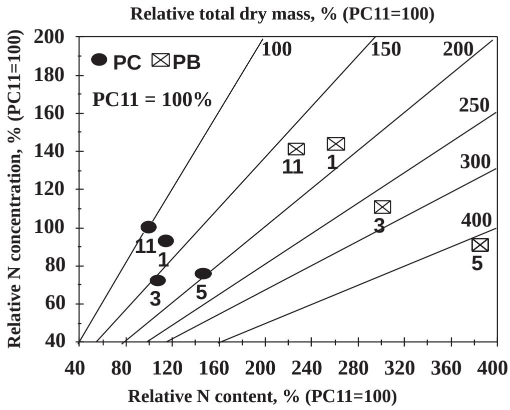

Fig. 5. Relative responses for total dry mass, N content and N concentration for two containerized Maritime pine seedling lots (PC = plastic containers 82 cm^3, PB = peat blocks 200 cm^3) sown on June 30. Seedling attributes were measured before planting, every two months (11: November, 01: January, 03: March, 05: May).

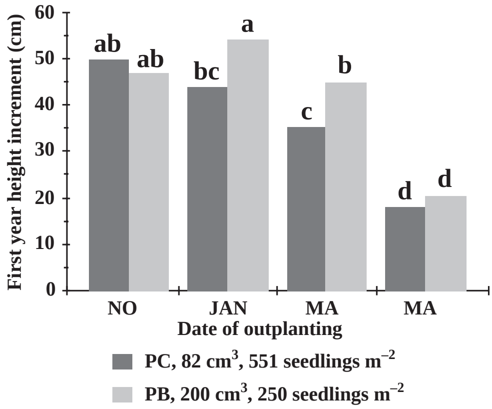

Fig. 6. First year height growth after outplanting for two containerised seedling lots (PC: plastic containers, PB: peat blocks) sown on June 30, for Maritime pine in the southwestern France. Similars letters represent no statistically differences among treatments (P < 0,05) according to Tukey’s studentized range test.

noted if planting was done from November to March, height growth decreased significantly (P < 0.05) for May. No mortality was registred from November to May plantings for both container types.

Comparing the two container types for a same outplanting date

Height growth for the seedlings grown on peat blocks was significantly better for January or March outplanting. In that case, peat block seedlings were the largest and had the highest nitrogen concentration. In November, there was no difference between containers, probably due to peat block seedlings root pruning 15 days before outplanting.

For late outplanting date (May), there was no difference on the height growth, despite various seedling size; the corresponding nitrogen concentration monitored at that time, was low, less than 1 %.

4 Discussion

Within each trial, it is difficult to separate the effect of seedling size and their nutrient status on the first subsequent height growth after planting. However the results of the three trials indicate that whatever was the seedling morphology, size, biomass or shoot/root ratio, the best first year height growth in the field was always associated with a high level of seedling N concentration before planting. The same results were previously observed on other conifer species (Benzian et al. 1974, Van den Driessche 1985, Munson and Timmer 1989 a, b, Timmer and Munson 1991, Timmer et al. 1991). To improve reforestation success and to counter soil fertility variation, one of the best ways seems to use preconditioned seedlings for outplanting during nursery stage (Duryea and Brown 1984). However, the optimal level of N concentration is not still precise for Maritime pine container seedlings; for our study in the range of N concentrations tested, height growth deficiency seems to appear below a level of 1.1–1.2 %. For a same seedling size, increasing nutrient concentrations increased stored nutrients available for new shoot growth after outplanting and confirm the importance of retranslocation from senescent material to new tissues in the conifer species (Gezelius et al. 1981, Fife and Nambiar 1984, Thivolle-Cazat 1990, Cocker 1991). Automnal fertilization supply in the nurseries have often improved subsequent seedling growth after planting (Benzian et al. 1974, Van den Driessche 1985). The common practices of fertilization in the commercial nurseries is realised by mixing slow release fertilizers in the substrate before sowing or sometimes with a constant nutrient supply with irrigation (soluble fertilizers). Biomass of the seedlings increase rapidly with the season and in the same time the nutrient concentration decreased with growth dilution and leaching just before planting (Timmer et al. 1991).

Those fertilization schedules seem not to be adapted and can sometimes explain planting failures. New fertilization schedules based on an exponential nutrient loading during exponential growth phase in nursery have already been proposed (Ingestad 1979, Ingestad and Kähr 1985, Troeng and Ackzell 1988, Timmer and al. 1991). Some new computerized systeme are also proposed and already used in nurseries to calculate various fertilization schedules based on seedling growth needs (Girard and Langlois 1989, Langlois and Gagnon 1993).

In this study, late sowing in nursery gave the best growth in the field but the effect of culture duration was perhaps mixed up with the decreasing nitrogen concentration due to the inadapted fertilization regime. With containerized seedlings, culture duration can also affect the root growth capacity after planting in relation with high root density in small size rigid containers (Salonius and Beaton 1994, Verger and Ginisty 1995) and the future growth of transplanted trees. Too long culture duration in nursery can also induce root deformation, decreasing tree stability, even if seedlings are grown in containers with guide bars (Carlson et al. 1980, Crémière 1994, Thompson and Schultz 1995, Lindström and Håkansson 1995).

Afforestation failure can arrive with high quality containerized seedlings when planting is done out of the normal season. With the conventional sowing dates used by commercial nurseries (June to July) the optimal afforestation season is October to March. The planting season could perhaps be extended with late sowing (August or September) in nursery and a particular attention to winter storage.

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