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Effects of Nursery Cultivation Regimes on Roots, Stems and Leaves of *Pistacia atlantica* Desf Seedlings

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Abstract

This research was conducted to evaluate the responses of *Pistacia atlantica* Desf seedlings to treatments of time (December 19th, February 05th and March 11th), depth (1, 2 and 3 cm), and soil of seed cultivation bed (pure forest soil, sandy soil, nursery soil and mixed forest soil) in a nursery in Lorestan province of Iran. Seeds were planted into plastic vases and since June the vegetative parameters of seedlings were measured. Results showed that seedlings cultivated in February had a more height, leaf numbers and vitality than those cultivated in December and March. The collar diameter in March cultivation was the lowest. Seedlings survival was 24.04% and 1.8% in December and March cultivations, respectively. The seedlings height in cultivation depth 1cm and 2 cm was significantly more than 3 cm. Seedlings with most vitality can be seen in the cultivation depth 1 cm. A trend of decreasing leaf numbers was observed when the depth of cultivation became more. The survival rate in cultivation depth 1 cm was more than 3 cm. The stem length was nearly the same in three time treatments, while the stem length significantly declined with increasing cultivation depth. On average, the seedlings in cultivation depth 3 cm had significantly highest stem: root dry weight ratio. Different soil treatments had significant effects on different growth properties of seedlings except for effects on root length and stem: root length ratio. Grown seedlings on the forest soil had highest height, vitality, leaf number and survival, while the stem: root dry weight ratio for grown seedlings on this soil type was the least. The greatest collar diameter growth was observed on nursery soil. In conclude the cultivation time of December, cultivation depths 1 cm and 2 cm and nursery soil had better affect on vegetative parameters of *Pistacia atlantica* Desf seedlings.

Keywords: *Pistacia atlantica* Desf, time treatment, cultivation depth, soil type, seedling production, Iran.

INTRODUCTION

Pistacia atlantica Desf has a broad geographic range from the Canaries and the Atlas Mountains in the west to the mountains of Afghanistan and Iran in the east. It is a dominant tree in its natural areas, and plays an important economic role in these regions, being used as rootstock for pistachio trees [5, 9, 14, 19]. Pistacia is a genus of the Anacardiaceae. Zohary [20] recognized 11 Pistacia species based on morphology: *P. mexicana* Kunth., *P. texana* Swingle., *P. lentiscus* L., *P. weinmannifolia* Poisson., *P. saportae* Burnat., *P. atlantica* Desf., *P. vera* L., *P. khinjuk* Stocks., *P. terebinthus* L., *P. palaestina* Bois. and *P. chinensis* Bunge. *P. saportae* was later recognized as an inter-specific hybrid.

The diameter growth of trunk and height of the seedlings and budding success were investigated to determine seedling characteristics of some *Pistacia* species under Gaziantep ecological conditions. The best seedling growth was measured on *Pistacia vera* (cv. Kirmizi) in the first period (first four months). The best diameter growth of trunk occurred on UCB-1 and was followed by PG, *Pistacia vera* (cv. Kirmizi), *Pistacia khinjuk* Stocks, *Pistacia terebinthus* L. and *Pistacia atlantica* Desf respectively at the end of the vegetation period. The highest seedling height was obtained from the seedlings of UCB-1 and followed by the seedlings of *Pistacia vera* L. (cv. Kirmizi), PG, *Pistacia atlantica*, *Pistacia terebinthus* L., *Pistacia khinjuk* Stocks. The budding success occurred on *Pistacia atlantica* Desf.,

Pistacia vera L. (cv. Kirmizi), PG and was followed by *Pistacia terebinthus* L. and *Pistacia khinjuk* Stocks [1, 6, 7].

The chemical composition of the fruits of the north algerian ecotype Pistacia atlantica subsp. atlantica was determined and compared to other fruits of different species in the genus growing in south Algeria and other Mediterranean regions. These fruits were analyzed for their dry matter, protein, crude oil, ash, fatty acids, and phytosterol content. The main fatty acids identified by gas chromatography were oleic (54.15%), linoleic (28.84%), and palmitic (12.21%) acids. The fruits of the north ecotype were found to be rich in protein, oil, fiber, and unsaturated fatty acids, suggesting that they may be valuable for food uses. The sterols isolated were campesterol, stigmasterol, b-sitosterol, and D5-avenasterol with b-sitosterol as the major constituent (85%±0.85). The biochemical data indicated an elevated MUFA rate (~56%) in pistacia oil which may be important against certain pathologies for its nutritional and preventive virtues [2, 8, 11, 13, 16].

In *Pistacia* flowering occurs before vegetative development, and males tend to flower before females (protandry). Females and males invest more energy in reproduction (that is, seed and fruits) and in flowering early before leaf production. So resources allocated to the development of vegetative growth, including photosynthetic tissues (leaf) in *P. atlantica* males, may be limited or unsteady [9]. This drought-tolerant tree, with an extensive root system, has been the subject of several studies aimed at selecting ecotypes best-adapted to present weather and soil conditions. In addition to its ecological use in reforestation programs and land preservation it has the advantage of being a good root stock and a good pollinator for the economic important *Pistacia vera* [3, 4, 10, 18].

Two wild pistachio species and the cultivated pistachio were evaluated for resistance to the common pistachio psylla, a major pest of pistachio trees, in a laboratory trial. The results of this study showed the causes of resistance in tested materials. It was found that the cultivated pistachio, *P. vera* with high fruit quality, were more favorable to the common pistachio psylla than that of wild pistachio species with poor nut quality [15]. Onay et al. [17] reported that the *in vivo* micrografting system provided good growth and development for new axillary shoots of pistachio (*P. vera* L.). These plantlets were successfully transplanted and there were no problems in establishment of micrografted plants in soil. The recovery of microscions was slow, but the use of micrografts onto herbaceous rootstocks a useful technique.

The goal of this study is to test the following hypotheses: *Pistacia atlantica* Desf seedlings growth and survival will change as a result of the different treatments of cultivation depth (1,2 and 3 cm), cultivation time (December 19th, February 05th and March 11th) and soil of cultivation bed (pure forest soil, sandy soil, nursery soil and mixed forest soil).

MATERIAL and METHOD

Study site

The Shoorab nursery with approximately 3 ha in size (1 ha for producing vases seedlings and 2 ha for treasure) is located 13 km southwest of Khoram Abad city, adjacent Khoram Abad-Andimeshk high way in Lorestan province (33˚25′4″ to 33 ˚25 ′35″ N, 48˚10′17″ to 48 10 ′33″ E, elevation 1180 m). The average annual precipitation is 477.94 mm. The average temperature during the coldest month is 5.3 ˚C and during the hottest month is 29 ˚C. Relative air humidity ranges from 32% in summer to 63% in winter. Average relative air humidity in our study area is 48%. According to Domarton approach, the climate is mid arid (I=18.17). The soils are classified as Regosols and Lithosols. The soil depth is greater than 70 cm. The bedrock is typically Conglomerate, limestone and young alluvial.

Nursery and seed conditions

The Shoorab nursery is irrigated by pumping and spouting water from Khoram Abad stream. In this study, the required seeds were collected from Aligodarz region. The capability of *Pistacia atlantica* Desf seeds to germinate was 44 % and the weight of thousands of them was 199.8 gr. *Pistacia atlantica* Desf seeds have thick and stable mesocarp. So in order to dormancy breakage, the seeds were imbibed in warm water for 24-48 hour. Seeds imbibing in water causes that the fractions be appeared on the seeds surface. Then, the seeds epicarp which is usually thin, fleshy, light to dark green or red in color were removed from seeds surface. The seeds were disinfected by fungicide after extracting from warm water.

Treatments

The study was carried out based on randomized complete block method and factorial experiment with four 100 replications in each treatments. The treatment includes (1) time of seeds cultivation in December 19th, February 05th and March 11th, (2) depth of seeds cultivation at the depths of 1, 2 and 3 cm and (3) soil of cultivation bed (a) pure forest soil composing 0-10 cm of surface soil (b) sandy soil (c) nursery soil composing sand, common soil and livestock muck in ratio 3:1:1 and (d) mixed forest soil composing sand, forest soil and litter in ratio 1:1:1. According to these treatments, 5-7 seeds were planted into the plastic vases. After rainfall season, the irrigation was performed for two or three days in week for all vases. Hand weeding operation was done during growing season for three times.

Growth variables measurement

Since June, the qualitative and quantitative characteristics if seedlings including height, collar diameter, leaf numbers, stem length, root length, survival, vitality and ratios of stem length: root length, stem dry weight: root dry weight were measured. 20% of seedlings in each replication were extracted from vases and their roots and stems were completely separated. In lab, the length of these organs were measured by ruler and then oven dried at 70 ˚C for at least 48 h. The dry weight of stems and roots were obtained by digital weighting with an accuracy of gr.

Seedlings height was measured by ruler with an accuracy of mm. Also, seedlings vitality was classified according to the leaves color. Class 1 include of seedlings with very low vitality (0-30% of leaves were completely green and without pale), class 2 include of seedlings with medium vitality (30-70% of leaves were completely green and without pale), class 3 include of seedlings with high vitality (70-100% of leaves were completely green and without pale). Collar diameter of *Pistacia atlantica* Desf seedlings was measured by a vernier caliper with an accuracy of mm. Seedling numbers in each treatment were counted for determining survival percent.

Soil measurements

Four samples from each soil treatment were randomly selected and then analyzed for determining soil chemical and physical properties. Soil texture was determined by the Bouyoucos hydrometer method (Bouyoucos 1962). PH was measured using an Orion Ionalyzer Model 901 pH meter in a 1:2.5, soil: water solution. EC (electrical conductivity) was determined using an Orion Ionalyzer Model 901 EC meter in a 1:2.5, soil: water solution. Soil organic carbon was determined using the Walkley–Black technique (Walkley 1947). The available P was determined with spectrophotometer by using Olsen method. The available K was determined by ammonium acetate extraction at pH 9.

Statistical analyses

All data were subjected to analysis of variance (ANOVA) using the Proc GLM procedure of SAS (SAS Institute Inc. 2000). Wherever treatment effects were significant the SNK test (Student Newman Kouls) at probability levels of 1% and 5% was carried out to compare the means. The graphs drawing were done in EXCEL software.

RESULTS and DISCUSSION

Effects of cultivation time treatments on seedlings growth

P. atlantica Desf. subsp. mutica (Fisch. et C. A. Mey.) Rech. f. is a highly resistant rootstock to rootknot nematodes compared with P. vera, P. palestina Boiss. and P. khinjuk [12]. In this study seedlings height and vitality was affected by cultivation time treatments (Table 1). In February, seedlings had a more height (74.70 mm) than those which were cultivated in December (70.57 mm) and March (65.63 mm). In addition, seedlings vitality cultivated in February was more than those cultivated in December and March (Table 2).

Table 1 displays that the collar diameter of the seedlings were quite different from each other due to cultivation time. The highest diameter of collar occurred in December (2.56 mm) and February (2.48

Table 1. Summary of the Analysis of Variance (ANOVA) for Growth Parameters of Pistacia atlantica Desf Seedlings in Different Cultivation Time

Variables	df	SS	MS	F
Height growth	2	1576.22	788.11	58.96**
Vitality	2	2.95	1.47	107.51**
Collar diameter	2	5.79	2.89	8.38**
Leaf numbers	2	48.13	24.06	24.16**
Survival	2	12959.09	6479.53	1237.34**
Root length	2	2.92	1.46	0.01ns
Stem length	2	13.51	6.76	2.52ns
Stem: root length ratio	2	0.03	0.01	1.04ns
Stem: root dry weight ratio	2	0.07	0.04	2.09ns

**, Significant at probability level of 1%, ns: not significant

mm) cultivations, while the collar diameter in March cultivation was the lowest (2.05 mm). Leaves number of *Pistacia atlantica* Desf seedling have shown significant differences in various cultivation times. Maximum and minimum leaf numbers was observed in February (9.35) and March (8.55) cultivations, respectively (Table 2).

Seedlings survival was significantly affected by cultivation time treatments (Table 1). Mean values for seedlings survival was 24.04% and 1.8% in December and March cultivations, respectively. The stem length was nearly the same in three time treatments (Table 2). The treatment of cultivation time had no significant effect on root length, stem: root length ratio and stem: root dry weight ratio (Table 1).

Effects of cultivation depth treatments on seedlings growth

Significant differences were found among seedlings height and vitality in different cultivation depth treatments (Table 3). The height of *Pistacia atlantica* Desf seedlings at the cultivation depth of 1cm (72.94 mm) and 2 cm (72.46 mm) was significantly more than cultivation depth of 3cm (65.46 mm). Seedlings with most vitality can be seen in the cultivation depth of 1 cm (Table 4).

No significant difference was found between the collar diameters of seedlings in various cultivation depths (Table 3). Table 2 reveals a trend of decreasing leaf numbers of *Pistacia atlantica* Desf when the depth of cultivation became more. The mean of leaf numbers in cultivation depths of 1, 2 and 3 cm were 9.37, 9.07 and 8.47, respectively.

Seedlings survival was significantly affected by cultivation depth treatments (Table 3). The survival rate of seedlings in cultivation depth of 1 cm was maximum (14.15%) and in cultivation depth of 3 cm was minimum (10.28%). The stem length significantly declined with increasing cultivation depth. The stem length of *Pistacia atlantica* Desf seedling was 7.27, 7.19 and 6.18 cm in cultivation depths of 1, 2 and 3 cm, respectively (Table 4). The treatment of cultivation depth had no significant effect on root length and stem: root length ratio. On average, the seedlings in cultivation depth of 3 cm had significantly highest stem: root dry weight ratio (0.56) (Table 3).

Effects of soil treatments on seedlings growth

The properties of different soil treatments ha been shown in Table 5. Also, Table 6 shows the significant differences among seedlings height under soil treatments. The grown seedlings in pure forest soil and mixed forest soil had mean height growth of 75.39 mm and 74.23 mm, respectively. The lowest height growth for *Pistacia atlantica* Desf seedlings (48.08 mm) was observed in sandy soil. Seedlings with more vitality were in the pure forest soil and mixed forest soil. The collar diameter was the lowest in sandy soil treatment. In addition, no statistically significant difference was observed between the collar diameter of seedlings in the nursery soil, pure and mixed forest soil. Soil treatments had significant effect on leaves number of seedlings. The maximum and minimum leaves for seedling were observed in pure forest soil (10.53) and sandy soil (5.04), respectively (Table 7).

There was significant difference between the seedlings survival in different soil treatments. In pure forest soil, seedlings had highest survival rate (15.82%) and in sandy soil they had lowest survival rate (7.68%). The seedlings grown in sandy soil had lower stem length (5.28 cm) compared to other soil treatments. The root length did not differ between the nursery soil, sandy soil, pure and mixed forest soil. In addition, soil treatments had not significant effect on stem: root length ratio. The stem: root dry weight ratio for grown seedlings on the nursery soil (0.58) and mixed forest soil (0.53) was more than the seedlings grown on the sandy soil (0.43) and pure forest soil (0.42) (Table 7).

Interaction between cultivation time, depth and soil treatments

Also, a significant interaction existed between cultivation depth, time and soil treatments (Table 8). This composition had significant effect on seedlings height growth. The seedlings height in cultivation time December, in cultivation depth 2 cm and in nursery soil

Table 2. Comparison of the Growth Parameters of Pistacia atlantica D. Seedlings in Different Cultivation Times

Variables / Cultivation time	Height growth (mm)	Vitality	Collar diameter (mm)	Leaf numbers	Survival (%)	Root length (cm)	Stem length (cm)	Stem: root length ratio	Stem:root dry weight ratio
December 19th	70.57 [b]	2.46 [b]	2.55 [a]	9.01 [a]	24.04 [a]	28.84 [a]	6.96 [a]	0.28 [a]	0.53 [a]
February 05th	74.70 [a]	2.64 [a]	2.48 [a]	9.34 [a]	8.78 [b]	30.24 [a]	7.14 [a]	0.29 [a]	0.49 [a]
March 11th	64.63 [c]	2.32 [c]	2.05 [b]	8.55 [b]	1.80 [c]	30.48 [a]	6.52 [a]	0.26 [a]	0.49 [a]

Table 3. Summary of Analysis of Variance (ANOVA) for Growth Parameters of Pistacia atlantica Desf Seedlings in Different Cultivation Depth

Variables	df	SS	MS	F
Height growth	2	1343.34	671.67	50.25**
Vitality	2	1.12	0.56	41.04**
Collar diameter	2	1.21	0.60	1.75ns
Leaf numbers	2	29.09	14.55	14.61**
Survival	2	308.87	154.44	29.49**
Root length	2	50.77	25.38	0.13ns
Stem length	2	16.78	8.39	3.13*
Stem: root length ratio	2	0.04	0.02	1.44ns
Stem: root dry weight ratio	2	0.13	0.07	3.66*

**, Significant at probability level of 1%, ns: not significant

Table 4. Comparison of the Growth Parameters of Pistacia atlantica D. Seedlings in Different Cultivation Depths

Variables / Cultivation depth	Height growth (mm)	Vitality	Collar diameter (mm)	Leaf numbers	Survival (%)	Root length (cm)	Stem length (cm)	Stem: root length ratio	Stem: root dry weight ratio
1 cm	72.94 a	2.56 a	2.55 a	9.37 a	14.16 a	29.71 a	7.27 a	0.30 a	0.50 a
2 cm	72.46 a	2.42 b	2.27 a	9.07 a	12.89 b	30.80 a	7.19 a	0.29 a	0.47 b
3 cm	65.46 b	2.44 b	2.32 a	8.47 b	10.28 c	28.75 a	6.18 b	0.25 a	0.55 a

In a same column, values with same superscript are not significantly different based on SNK test.

Table 5. Comparison of the Chemical and Physical Properties of Soil Treatments

Treatment	Pure forest soil	Mixed forest soil	Nursery soil	Sandy soil
pH	7.57	7.59	7.53	7.55
EC (mS cm^{-1})	5.38	5.56	2.77	4.34
T.N.V (%)	50.63	49.72	47.37	53.67
Organic C (%)	2.08	1.99	0.69	0.21
P (P.P.m)	4.30	17.37	43.25	3.05
K (P.P.m)	235.75	158.75	63.75	66.25
N (%)	0.22	0.30	0.285	0.14
Sand (%)	19.00	68.25	80.50	89.25
Silt (%)	55.00	19.50	15.50	6.75
Clay (%)	26.00	12.25	4.00	4.00

Table 6. Summary of Analysis of Variance (ANOVA) for Growth Parameters of Pistacia atlantica Desf Seedlings in Different Soil Treatments

Variables	df	SS	MS	F
Height growth	3	2449.33	816.44	61.08**
Vitality	3	12.54	4.18	304.99**
Collar diameter	3	4.67	1.56	4.51**
Leaf numbers	3	230.47	76.82	77.14**
Survival	3	2044.34	681.45	130.13**
Root length	3	717.41	239.14	1.21ns
Stem length	3	35.43	11.81	4.41**
Stem: root length ratio	3	0.12	0.04	2.86ns
Stem: root dry weight ratio	3	0.48	0.16	8.95**

**, Significant at probability level of 1%, ns: not significant

Table 7. Comparison of the Growth Parameters of Pistacia atlantica D. Seedlings in Soil Treatments

Variables / Soil treatments	Height growth (mm)	Vitality	Collar diameter (mm)	Leaf numbers	Survival (%)	Root length (cm)	Stem length (cm)	Stem: root length ratio	Stem: root dry weight ratio
Pure forest soil	75.39 a	2.71 a	2.42 a	10.53 a	15.82 a	31.36 a	6.87 a	0.28 a	0.42 b
Mixed forest soil	74.23 a	2.67 a	2.43 a	8.78 b	10.77 c	26.59 a	7.24 a	0.33 a	0.53 a
Nursery soil	70.01 b	2.27 b	2.62 a	9.15 b	13.22 b	32.79 a	7.07 a	0.25 a	0.58 a
Sandy soil	48.08 c	1.87 c	1.53 b	5.04 c	7.68 d	25.32 a	5.28 b	0.23 a	0.44 b

In a same column, values with same superscript are not significantly different based on SNK test.

was highest (88.86 mm) (Table 9).

The interaction among time, depth and soil treatments was significant on seedlings vitality. February cultivation at the depth of 2 cm of pure forest soil had the highest vital seedlings. The results of our study demonstrate that the interactions among treatments can strongly affect the seedlings collar diameter. Most of the collar diameter (4.17 mm) has appeared in December cultivation at the depth 1 cm of mixed forest soil. Gholami et al. [7] detected that the survival of *Pistacia atlantica* seedlings was greater at 4 cm by sowing dates which is in 9th, 29th of January than at 8 cm sowing depth by 18th of February. Collar diameter and height were significantly greater in nursery soil and 9 January and 29 January sowing date but were not different among sowing depths. Shoot: root ratio and shoot: root dry weight ratio was significantly lower in forest soil but not affected by sowing date. Shoot: root dry weight ratio was lower in 4 cm sowing depth while shoot:root ratio did not show any difference among sowing depth. In general soil type, sowing date and sowing depth are factors that can be influenced on physical and morphological traits of seedlings.

The ANOVA analysis showed a significant difference between the mean leaf numbers after treatments composition (Table 8). Leaf numbers in December cultivation at the depth 3 cm of pure forest soil was highest. Maximum survival rate (38.90%) was observed in December cultivation at the depth 1 cm of nursery soil (Table 9). Interaction among cultivation depth, time and soil treatments hadn't significant effect on stem length, root length and stem: root length ratio of *Pistacia atlantica* Desf seedlings (Table 8). Stem: root

dry weight ratio was significantly affected by treatments composition. Stem: root dry weight ratio in December cultivation at the depth 2 cm of nursery soil was highest (0.85) (Table 9).

In conclude the cultivation time of December, cultivation depths of 1 cm and 2 cm, nursery soil had better effects on vegetative parameters of *Pistacia atlantica* Desf seedlings. Hosseini et al. [8] demonstrated that the survival of *Pistacia atlantica* seedlings was significantly affected by sowing depth but not by sowing date and weed treatment. Survival was greater at 4 cm than at 8 cm sowing depth. Collar diameter was significantly greater at 4 cm than at 8 cm sowing depth and in 9 January and 29 January than in 18 February sowing date but was not different between weed treatments. Shoot/root length ratio and height was not affected by sowing date, sowing depth and weed treatment. Shoot:root dry weight ratio was significantly lower at 4 cm sowing depth but not affected by sowing date. This ratio was greater in weed competition condition.

CONCLUSIONS

Results showed that in February, seedlings had a more height than those cultivated in December and March. In addition, seedlings vitality cultivated in February was more than those cultivated in December and March. The maximum and minimum leaf numbers was occurred in February and March cultivations, respectively. The collar diameter in March cultivation was the lowest. Seedlings survival was 24.04% and 1.8% in December and March cultivations, respectively. The seedlings height in cultivation depth of 1cm and 2 cm was significantly more than 3 cm. Seedlings with most vitality can be seen in the cultivation depth of 1 cm. A trend of decreasing leaf numbers was observed when the depth of cultivation became more. The survival rate in cultivation depth of 1 cm was more than 3 cm. The stem Length was nearly the same in three time treatments, while the stem length significantly declined with increasing cultivation depth. On average, the seedlings in cultivation depth of 3 cm had significantly highest stem: root dry weight ratio. Also, this study showed that the soil treatments had significant effects on different growth properties of seedlings except for root length and stem: root length ratio. Grown seedlings on the forest soil had most height, vitality, leaf number and survival, while the stem: root dry weight ratio for grown seedlings on this soil type was least. The most collar diameter was observed for grown seedlings on the nursery soil. In conclude the cultivation time of December, cultivation depths of 1 cm and 2 cm and nursery soil had better effects on vegetative parameters of *Pistacia atlantica* Desf seedlings.

Table 8. Summary of Analysis of Variance (ANOVA) for Growth Parameters of Pistacia atlantica Desf Seedlings According to Interaction of Cultivation Time, Depth and Soil Treatments

Variables	df	SS	MS	F
Height growth	4	337.80	84.45	6.32^{**}
Vitality	4	0.58	0.14	10.56^{**}
Collar diameter	4	1.68	0.42	1.22^{ns}
Leaf numbers	4	52.99	13.25	13.30^{**}
Survival	4	174.70	43.67	8.34^{**}
Root length	4	1339.57	334.89	1.69^{ns}
Stem length	4	4.04	1.01	0.38^{ns}
Stem: root length ratio	4	0.15	0.04	2.86^{*}
Stem: root dry weight ratio	4	0.04	0.01	0.53^{ns}

**, Significant at probability level of 1%, ns: not significant

Table 9. Treatments Interactions on Growth Parameters of Pistacia atlantica Desf Seedlings

Growth parameters	Treatments	December			February			March		
		1cm	2cm	3cm	1cm	2cm	3cm	1cm	2cm	3cm
Height growth	Pure forest soil	72.70	82.48	82.72	84.05	71.93	72.20	75.22	79.37	57.83
	Mixed forest soil	79.05	78.07	71.02	72.86	81.85	66.68	78.09	68.81	71.62
	Nursery soil	83.83	88.86	67.86	77.93	76.41	70.31	63.21	52.59	49.10
	Sandy soil	44.00	51.09	45.21	67.00	0.00	0.00	45.00	0.00	0.00
Vitality	Pure forest soil	2.63	2.66	2.78	2.75	2.87	2.71	2.74	2.62	2.66
	Mixed forest soil	2.63	2.56	2.57	2.84	2.69	2.79	2.84	2.62	2.52
	Nursery soil	2.41	2.75	2.50	2.72	2.36	2.45	2.04	1.39	1.79
	Sandy soil	2.41	1.99	1.65	1.00	0.00	0.00	1.00	0.00	0.00
Collar diameter	Pure forest soil	3.02	2.66	3.05	2.50	2.82	2.16	2.01	2.25	1.82
	Mixed forest soil	4.17	2.48	2.33	2.23	2.18	2.24	2.00	2.00	2.20
	Nursery soil	2.70	2.75	2.59	2.88	3.03	3.17	2.65	1.69	2.15
	Sandy soil	1.75	1.73	1.44	0.90	0.00	0.00	0.90	0.00	0.00
Leaf numbers	Pure forest soil	10.06	12.37	13.36	10.09	9.95	9.76	11.37	9.62	8.17
	Mixed forest soil	7.99	8.60	9.33	8.87	8.50	6.82	10.79	9.94	8.12
	Nursery soil	10.54	12.37	8.13	10.16	9.56	11.22	8.58	6.15	5.60
	Sandy soil	6.07	5.09	4.22	6.00	0.00	0.00	3.00	0.00	0.00
Survival	Pure forest soil	28.15	37.25	38.20	10.40	14.05	8.00	4.30	1.15	0.85
	Mixed forest soil	23.27	28.55	26.05	9.20	0.95	1.90	5.10	1.05	0.35
	Nursery soil	38.90	10.85	15.80	22.05	13.60	6.90	1.80	1.40	1.05
	Sandy soil	15.95	27.50	7.55	1.00	0.75	0.62	0.25	0.37	0.00

Root length	Pure forest soil	33.53	47.84	28.06	32.94	51.90	26.41	23.75	21.30	16.52
	Mixed forest soil	23.87	23.01	18.04	14.86	26.26	28.38	44.07	27.44	33.40
	Nursery soil	47.30	19.93	28.57	20.27	29.98	41.19	27.75	34.70	45.40
	Sandy soil	28.73	23.64	21.58	0.00	0.00	0.00	0.00	0.00	0.00
Stem length	Pure forest soil	7.69	7.38	7.11	7.60	5.13	6.25	7.42	7.68	5.54
	Mixed forest soil	7.50	8.62	6.44	6.86	8.92	7.18	5.36	7.36	6.90
	Nursery soil	8.97	8.02	4.84	8.85	6.94	6.49	7.61	5.62	5.20
	Sandy soil	4.82	6.19	5.89	0.00	0.00	0.00	0.00	0.00	0.00
Stem: root length	Pure forest soil	0.23	0.23	0.25	0.32	0.11	0.28	0.34	0.38	0.36
	Mixed forest soil	0.36	0.40	0.38	0.47	0.34	0.30	0.16	0.32	0.21
	Nursery soil	0.25	0.42	0.21	0.42	0.24	0.17	0.28	0.17	0.11
	Sandy soil	0.19	0.26	0.23	0.00	0.00	0.00	0.00	0.00	0.00
Stem: root dry weight	Pure forest soil	0.68	0.34	0.58	0.40	0.29	0.40	0.40	0.38	0.30
	Mixed forest soil	0.56	0.41	0.49	0.53	0.60	0.57	0.59	0.46	0.59
	Nursery soil	0.44	0.85	0.65	0.61	0.40	0.64	0.40	0.66	0.61
	Sandy soil	0.35	0.32	0.64	0.00	0.00	0.00	0.00	0.00	0.00

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