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Effect of spacing, nitrogen fertilizer (with and without organic manure) and seed bed density on the growth of Allepo pine seedling in nursery in Kashmir Valley

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Abstract
Four types of spacing viz. 2.5 x 5cm (B_1), 5 x 5cm (B_2), 10 x 5cm (B_3) and 10 x 10cm (B_4) along with fertilizer viz. control (F_0), 50 kg N ha^{-1} (F_1), 100 kg N ha^{-1} (F_2), 150 kg N ha^{-1} (F_3), N_{50}+1.0 t FYM ha^{-1} (F_4), N_{50}+1.5 t FYM ha^{-1} (F_5), N_{100} + 1.0 t FYM ha^{-1} (F_6) and N_{100} + 1.5 t FYM ha^{-1} (F_7) were used to assess their effect on survival and growth parameters of seedlings. This experiment was laid out in factorial randomized block design with three replications each. All the seedling growth parameters increased with the increase in spacing except plant height which was found maximum (22.27cm) at narrow spacing (2.5 x 5cm). All other growth parameters viz. collar diameter (2.29 mm), root dry weight (0.30 g), shoot dry weight (0.63 g), shoot root ratio (2.13), total fresh biomass (2.53 g) and plant per cent (66.54%) were found maximum in seedlings at wider spacing (10 x 10 cm) and minimum values in these growth attributes were recorded in narrow spacing (2.5 x 5cm).The nitrogen fertilizer along with farm yard manure showed significant effect on seedling morphological characters. The maximum plant per cent (67.10), plant height (23.53cm), collar diameter (2.40 mm), dry root weight (0.35 g), dry shoot weight (0.74 g), shoot root ratio (2.16) and total fresh biomass (2.87 g) were recorded in seedlings supplied with N_{50}+1.5 t FYM ha^{-1} (F_5). The minimum values in all these parameters were recorded under control conditions. Under open nursery beds, the seedlings of *Pinus halepensis* on application of N_{50}+1.5 t FYM ha^{-1} in two equal splits (half at transplanting and another half after 30 days of transplanting) with 10 x 10 cm spacing is found to be the most promising treatment combination for producing more biomass per plant and healthy nursery stock.

Keywords: *Pinus halepensis*, fertilizers, seedlings growth parameters, nursery and factorial randomized block design.

Introduction
The allepo pine (*Pinus halepensis*) is a pine native to the Mediterranean region. It is generally found at low altitudes mostly from sea level to 200 m but even grow at an altitude of up to 1000 to 1700 m (Rushfroth, K, 1999) [15]. Allepo pine is an exotic conifer/ pine species in India and has been successfully introduced in Kashmir valley. Although the exact date of its introduction has not been ascertained but the tree has been found growing in Shankaracharya reserve forest (Srinagar), situated at an altitude of 1,970 m above m. s.l. Allepo pine is a small to medium sized tree reaching 15-25 m tall and with a trunk diameter of up to 60 cm exceptionally up to 1 m. The bark is an organ red, thick and deeply fissured at the base of the trunk and flanky in the upper crown, the leaves (needles) are very slender 6-12 cm long distinctly yellowish green. Allepo pine is widely planted for timber in its native areas. It is also a popular ornamental tree extensively planted in parks and gardens in hot dry areas. It is also extensively grown as wind break and for soil conservation. A resin from the trunk is used for chewing and flavoring wine. The turpentine obtained from the resin is antiseptic, diuretic, rubefacient and vermifuge. It is also used for complaints of respiratory systems, kidney and bladder complaints (Grieve, 1984) [3]. The fertilizers can be organic (FYM, Cow dung, Peet, Sludge etc.) or inorganic (Urea, DAP, MoP etc.) in nature. The organic manures are capable of supplying different nutrients for growth of plants and also improve the soil physical properties like soil structure, aeration and water holding capacity etc. They have the ability to stimulate the activities of different soil micro-organisms through the supply of energy. They are usually considered to regulate the thermal regimes of the soil.

As it is not easy to arrange for requisite quantities of organic manures, the chemical fertilizers are being increasingly used. The inorganic fertilizer is a material intended to be applied to crop to promote their growth to increase crop yield and to improve crop quality. Fertilizers to be applied have to be determined for each species on the basis of experimental work. Like plants in the orchards or fields, nursery plants also require all major and minor nutrients in ample quantity. If there is deficiency of nutrients, it is likely to affect the plant performance and ultimately the quality of propagation material. Thus the nutrients must be present or supplemented artificially in the growing media for better growth in nursery because the natural regeneration of Allepo pine is generally absent. Hard to open cones, low germination potential, seed dormancy and infrequent good seed years are among the important factors responsible for the absence of natural regeneration.

Methods and Materials

The present investigation was conducted at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir during the years 2008-2010. The experimental site i.e. Forest Nursery at Shalimar is located between 34.08^{O}N latitude and 74.83^{O}E longitude at an altitude of about 1587 m above mean sea level whereas the average altitude of Kashmir valley (valley zone) ranges between 1500 to 2300 m above m.s.l. The experimental site is roughly 14 km south east to the Srinagar city and the soil of the nursery is well drained, silty loam type. The climate in general is temperate type. Winter is severe extending from December to March. The region faces a wide temperature range from a minimum of -8 ^{O}C in winter to a maximum of 33^{O}C in the summer. Winter frost is common and medium to heavy snow fall is also witnessed. The area receives an annual precipitation of 676-1193 mm.

1. Seed source

The cones of Allepo pine (*Pinus halepensis*) were collected from the Shankaracharya reserve forest in Srinagar (Kashmir) situated at an altitude of about 1,970 m above m.s.l. The seeds were extracted after drying the cones in the sun, and in controlled conditions accordingly, de-winged manually and all foreign matter was removed.

2. Layout and design

The experiment was laid out in a randomized block design with three replications. Four spacings and eight combinations of nitrogen fertilizers and farm yard manure were adopted. The plot size was kept as 1 m x 1 m.

3. Transplanting of seedling

One year old seedlings of Allepo pine were transplanted in to the experimental plots during the month of February and the observations were recorded on two year old (1-1) seedlings.

4. Treatments

The details of the treatments comprising four level of spacing and eight combinations of fertilizers and FYM are given below:

a) Seed bed density/ spacing

B1 : 800 seedlings/m2 (2.5 x 5 cm)
B2 : 400 seedlings/m2 (5 x 5 cm)
B3 : 200 seedlings/m2 (5 x 10 cm)
B4 : 100 edlings/m2 (10 x 10 cm)

b) Fertilizer

F0 : Control (No fertilizer)
F1 : 50 kg N ha-1
F2 : 100 kg N ha-1
F3 : 150 kg N ha-1
F4 : N50 + 1.0t FYM ha-1
F5 : N50 + 1.5t FYM ha-1
F6 : N100 + 1.0t FYM ha-1
F7 : N100 + 1.5t FYM ha-1

This experiment consists of 32 treatments with three replications each and was laid out in Factorial randomized block design.

100 Time of application

Nitrogen was applied in two split doses in the form of urea (46% N). The first dose was applied one month after transplanting and the second one month after the application of first.

101 Cultural operations

Seedlings were irrigated as and when required and weeding was done regularly at an interval of 10-15 days.

102 Observations recorded

- Seedling height
- Collar diameter
- Root and shoot weight
- Shoot: root ratio
- Total biomass of seedlings
- Plant per cent

Results and Discussions

It was apparent from year wise and average data in Table 01 to Table 06 that the effect of spacing, fertilizer and their interaction (B x F) exert significant effect on plant per cent and seedling growth parameters like plant height, collar diameter, dry root weight, dry shoot weight, shoot root ratio and total fresh biomass under nursery conditions. The average data in Table 01 revealed that the maximum plant per cent (66.54%) was recorded in seedlings planted at 10 x 10 cm spacing and the minimum (56.24%) was observed in seedlings planted at 2.5 x 5 cm spacing. Similar trend was observed in the parameter in both the years of investigation i.e. 2009 and 2010 (Appendix X). Like spacing, fertilization also significantly affected nearly all the growth parameters. An inquisition of pooled data in Table-01 revealed maximum plant per cent (67.10%) in seedlings receiving N_{50} + 1.5 t FYM ha^{-1} (F_5) and the minimum (53.28%) was obtained in seedling under control condition. Similar trend was observed in the parameter in both the years of investigation i.e. 2009 and 2010 (Appendix X). From the perusal of average data in Table-01, it is clear that maximum plant per cent (72.66%) was recorded in seedlings spaced/ transplanted at a spacing of 10 x 10 cm and receiving N_{50} + 1.5 t FYM ha^{-1} (B_4F_5). This was however, closely followed by the treatment combination of B_3F_5 (71.33%) and B_4F_4 (70.16%). The minimum plant per cent (45.54%) was recorded when seedlings were transplanted at a spacing of 2.5 x 5 cm under control (B_1F_0) condition. Almost similar trend was observed in the parameters during the years 2009 and 2010.Spacing of seedling in nursery beds influence almost all the seedling growth parameters (Table 01 to Table 06), there was significant increase in all the seedling growth parameters as the spacing was increased except the plant height which decreased with the increase in spacing. The perusal of the pooled data in Table-22 revealed maximum plant height (22.27 cm) in 2.5 x 5 cm spacing. This was however, followed by 5 x 5 cm spacing (B_2)

and 5 x 10 cm spacing (B_3) giving 16.25 cm and 14.60 cm values, respectively. The significantly least mean value 13.85 cm was observed in 10 x 10 cm transplanting spacing (B_4). Similar trend was observed in the parameter in both the years of investigation i.e. 2009 and 2010 (Appendix X).

An inquisition of average data in Table-02 revealed that plant height was significantly affected by the fertilizer doses. Significantly highest plant height of 23.53 cm resulted when seedlings receive N_{50} + 1.5 t FYM ha^{-1} (F_5) fertilizer dose. The significantly minimum plant height (15.62 cm) was recorded in seedlings under control condition. Similar trend was observed in the parameter in both the years of investigation i.e. 2009 and 2010 (Appendix X). As is evident from average date in Table-02 that significantly highest plant height of 27.16 cm was recorded in seedlings transplanted at a spacing of 2.5 x 5 cm and receiving N_{50} + 1.5 t FYM ha^{-1} (B_1F_5). This was however, followed by treatment combinations like B_2F_5 (25.38 cm), B_1F_4 (25.08 cm) and B_2F_4 (24.43 cm) giving values in descending order. The significantly minimum value of 13.85 cm was observed in seedlings transplanted at a spacing of 10 x 10 cm under control (B_4F_0) condition. A similar trend was observed in the parameters in both the years of investigation i.e. 2009 and 2010 (Appendix X).

It is evident from the Table-03 that there was a significant increase in the collar diameter of the seedlings as the spacing was increased. The significantly highest collar diameter of 2.29 mm was observed in wider spacing i.e. 10 x 10 cm which was statistically at par with (2.28 mm) in seedlings spaced at 5 x 10 cm. The minimum (2.10 mm) was observed in narrow spacing of 2.5 x 5 cm. A similar trend was also observed in the parameter in both the years of investigation i.e. 2009 and 2010 (Appendix X). A cursory glance of the average data in Table-03 revealed maximum collar diameter (2.40 mm) in seedlings receiving N_{50} + 1.5 t FYM ha^{-1} (F_5) which was statistically at par with (2.36 mm) in seedling fertilized with N_{50} + 1.5 t FYM ha^{-1} (F_4). The significantly minimum collar diameter (1.83 mm) was recorded under control condition (F_0). Almost similar trend was observed in both the years of investigation i.e. 2009 and 2010 (Appendix X). As is evident from pooled data in Table-03 that significantly highest collar diameter of 2.50 mm was recorded in seedling spacing at 10 x 10 cm and received N_{50} + 1.5 t FYM ha^{-1} (B_4F_5) which was statistically at par with B_4F_5 and B_3F_5 received the fertilizer doses of N_{50} + 1.5 t FYM ha^{-1} each at a spacing of 10 cm x 10 and 5 x 10 cm, respectively. The significantly minimum value of 1.60 mm was observed in seedlings spaced at 2.5 x 5 cm under control (B_1F_0). A similar trend was observed in the parameters in both the years of investigation i.e. 2009 and 2010 (Appendix X).

It was revealed from average data in Table-04 that significantly maximum dry root weight of 0.30 g was recorded in 10 x 10 cm spacing which was statistically at par with B_3 (0.29 g) when seedlings were transplanted at a spacing of 5 x 10 cm. The significantly minimum value of 0.26 g was recorded when seedlings were transplanted at a spacing of 2.5 x 5 cm. The almost similar trend was observed in both the years of investigation i.e. 2009 and 2010 (Appendix X). The average data in Table-04 indicated that the significantly maximum root dry weight of 0.35 g was recorded in seedlings receiving N_{50} + 1.5 t FYM ha^{-1}. This was however, closely followed by F_4 (0.32 g) and F_6 (0.30 g) giving values in descending order. The significantly least value of 0.22 g was observed in seedling grown under control condition (F_0). Similar trend was observed in both the years of investigation (Appendix X). It is evident from the average data in Table-04 that significantly maximum dry root weight of 0.39 g was recorded in seedlings transplanted at a spacing of 10 x 10 cm and receiving N_{50} + 1.5 t FYM ha^{-1} (B_4F_5) which was found statistically at par with the seedlings spaced at 5 x 10 cm and receiving N_{50} + 1.5 t FYM ha^{-1} (B_3F_5). The significantly minimum (0.20 g) dry root weight was observed in seedling transplanted at 5 x 5 cm under control (B_2F_0) which was statistically at par with the treatment combination of B_1F_0. The almost similar trend was observed in both the years of investigation (Appendix X).

The average data in Table-05 indicated that the significantly maximum dry shoot weight of 0.63 g was recorded in 10 x 10 cm spacing. This was however, closely followed by B_3 (0.58 g) and B_2 (0.56 g) giving values in descending order. The significantly minimum value of 0.51 g was recorded when seedlings were raised at a spacing of 2.5 x 5 cm. The almost similar trend was observed in both the years of investigation i.e. 2009 and 2010 (Appendix X). A critical review of data in Table-05 revealed that the significantly maximum dry shoot weight of 0.74 g was recorded in seedling receiving N_{50} + 1.5 t FYM ha^{-1} (F_5). This was however, closely followed by F_4 (0.65g) and F_6 (0.61g) giving values in descending order. The significantly least value of 0.44 g was observed in seedling growth under control condition (F_0). The almost similar trend was observed in both the years of investigation i.e. 2009 and 2010 (Appendix X). It is evident from the average data in Table-05 that the maximum dry shoot weight of 0.84 g was recorded in seedlings raised at a spacing of 10 x 10 cm and receiving N_{50} + 1.5 t FYM ha^{-1} (B_4F_5) which is however closely followed by B_3F_5 (0.75 g) and B_2F_5 (0.70 g). The minimum value of 0.40 g was observed in seedling raised at a spacing of 2.5 x 5 cm under control (B_1F_0) condition. The almost similar trend was observed in both the years of investigation (Appendix X).

The contents of Table-06 revealed that the shoot root ratio also showed the similar trends giving maximum value (2.13) in 10 x 10 cm spacing which was closely followed by B_3 (5 x 10 cm) (2.06) and B_2 (5 x 5 cm) (1.96) giving values in descending order. The significantly minimum value (1.92) was recorded in 2.5 cm x 5 cm spacing. The almost similar trend was observed in both the years of investigation (Appendix X). A cursory glance of the pooled data in Table-06 indicated maximum shoot root ratio (2.16 g) was recorded in seedling receiving N_{50} + 1.5 t FYM ha^{-1} which was closely followed by F_4 (2.08), F_6 (2.03) and F_7 (2.02) giving values in the descending order. The minimum (1.92) was recorded in seedlings under control condition. A cursory glance of the average data in Table-06 revealed maximum shoot root ration (2.27) in seedlings spaced at 10 x 10 cm, receiving N_{50} + 1.5 t FYM ha^{-1} (B_4F_5) which was statistically at par with (2.21) in seedlings spaced at 10 x 10 cm and receiving N_{50} + 1.5 t FYM ha^{-1} (B_4F_4). The minimum short root ratio (1.83) was recorded at 2.5 x 5 cm spacing under control (B_1F_0). The almost similar trend was observed in both the years of investigation (Appendix X).

The pooled data in the Table-07 revealed that the total fresh biomass of seedling increase with the increase in the spacing. The significantly maximum total fresh biomass of the seedling (2.53 g) was recorded in seedlings transplanted at a spacing of 10 x 10 cm which was closely followed by B_3 (2.40 g) and B_2 (2.23 g) and the minimum (2.11 g) was observed in seedlings transplanted at 2.5 x 5 cm spacing. Almost similar trend was observed in the years of 2009 and 2010 (Appendix X). It is evident from the average data in the Table-07 that maximum total fresh biomass of per seedling (2.87 g) was recorded in seedlings receiving N_{50} + 1.5 t FYM ha^{-1} which was however, closely followed by F_4 (2.63 g), F_6 (2.41 g) and F_7 (2.29 g) giving values in the descending order. The minimum (1.96 g)

was obtained in seedlings under control condition. The almost similar trend was observed in both the years of investigation (Appendix X).

The interaction effect of spacing and nitrogen fertilizer on the total fresh biomass of seedlings in nursery was presented in Table-20. The significantly maximum total fresh biomass of per seedling (3.18 g) was recorded in seedlings spaced at 10 x 10 cm receiving N_{50} + 1.5 t FYM ha^{-1} (B_4F_5) which was however closely followed by B_3F_5 (3.08 g) and B_4F_4 (3.06 g). The significantly minimum total fresh biomass per seedling (1.78 g) was observed when spaced at 2.5 x 5 cm under control (B_1F_0). The almost similar trend was observed in both the years of investigation i.e. 2009 and 2010 (Appendix X). The nitrogen fertilizer along with farm yard manure showed significant effect on seedling morphological characters of *Cedrus deodara.* The maximum plant per cent (68.67%), plant height (16.37 cm), collar diameter (2.48 mm), root dry weight (0.34 g), short dry weight (0.70 g) and total fresh biomass (2.94 g) were recorded in seedling supplied with N50+5t FYM ha^{-1} while maximum shoot root ratio (2.18) was recorded in seedlings supplied with 100 kg N ha^{-1}. The minimum values in all these parameters were recorded under control conditions (Sofi, 2005) [21].

Conclusions

Under open nursery beds, the seedlings of *Pinus halepensis* on application of N_{50}+1.5 t FYM ha^{-1} in two equal splits (half at transplanting and another half after 30 days of transplanting) with 10 x 10 cm spacing is found to be the most promising treatment combination for producing more biomass per plant and healthy nursery stock. Spacing of seedlings in the nursery beds influenced all seedling growth parameters (Table 01 to 07). All the parameters showed significant increase in growth attributes with the increase in spacing except plant height which decreased with the increase in spacing. The maximum plant per cent (66.54) was recorded at wider spacings (10 x 10 cm). Increase in the plant per cent with the corresponding increase in spacing may be ascribed to decreased competition between the nursery stock for light, nutrients, moisture and for available space. These results are in line with the findings of Sood (1999) [22]. The maximum plant height (22.27 cm) was recorded in narrow spacing and minimum (17.21 cm) at wider spacing. The increase in the plant height may be attributed to more competition under narrow spacing. On the other hand, the wider spacing exhibited maximum collar diameter (2.29 mm), root dry weight (0.30 g), shoot dry weight (0.63 g), shoot root ratio (2.13) and total fresh biomass (2.53 g). The minimum values in all these growth parameters were recorded in narrow spacing (Table 01 to 07). The increase in diameter growth with the corresponding increase in spacing may be ascribed to low plant population per unit area and reduced competition for soil moisture, nutrients and space. The results are in close conformity with the findings of Blok and Vontol (1983) [1]; Kaushal (1983) [6], Singh and Sharma (1984) [20], Malik (1987) [10], Massodi (1990) [11] and Sofi (2005) [21]. The maximum shoot root ratio was recorded at wider spacing. This is in close agreement with the findings of Simpson and David (1989) [19] in Douglas fir seedlings. The increase in biomass is evident as the individual component also registered an increased growth at the same spacing. The findings are in line with the studies of Van Den Driessche (1984) [23] in Douglas fir and sitka spruce, Singh and Sharma (1984) [20] in *Abies pindrow,* Mahajan (1990) [9] in *Robinia pseudoacacia* and Lal (1993) [8] in *Ulmus laevigata,* Masoodi (1990) [11] in *Acer oblongum* and Sofi (2005) [21] in *Cedrus deodara.* Thus the better uptake of mineral nutrients from the soil and high biochemical and nutrient composition of the seedlings at wider spacings may be responsible for better growth and development of seedlings in the nursery.

The study reveal that the fertilizer doses exert significant influence on plant per cent and all the growth parameters of the seedlings (Table 01 to 07). The maximum plant height (23.53 cm) and collar diameter (2.40 mm) was recorded in seedlings receiving N_{50}+1.5 t FYM ha^{-1} (F_5). Nitrogen being the essential constituent of proteins, chlorophyll, nucleic acid and protoplasm plays a significant role in plant growth. The increase in these growth parameters by application of nitrogen is understandable in view of the beneficial role of this element related with growth and development. Similar response for vegetative growth of other plant species to nitrogen application has been reported by Kaul *et al.* (1970) [5] in *Eucalyptus globulus*, Prasad *et al.* (1984) [13] in *Eucalyptus grandis,* Malik (1987) [10] in *Eucalyptus tereticornis.* Reinsvold and Pope (1987) [14] in *Robinia pseudoacacia.* An increase in height and diameter of three hybrids of poplars was observed by Shedy (1976) [18] with NPK treatment at the rate of 56 kg ha^{-1} under nursery condition. Deol and Khosla (1983) [6] also reported that application of 60 kg Nha^{-1} significantly enhanced plant height of *Populus ciliate* under nursery condition. Khurana (1989) [7] reported that under nursery condition application of 75 kg Nha^{-1} for maximum height and diameter growth of selected provenances (pooled together) of *Populus ciliata.* Sofi (2005) [21] also reported that application of N_{50}+ 5t FYM ha^{-1} significantly enhanced all the plant growth parameters of the seedlings of *Cedrus deodara* under nursery conditions.

The maximum plant per cent (67.10) was recorded in seedlings receiving N_{50}+1.5 t FYM ha^{-1} dose of nitrogen and organic fertilizer. Nitrogen is a major constituent of enzymes and change in nitrogen concentration of tissue generally reflects change in enzyme concentration. The results are in conformity with the findings of Mishra and Chauhan (1997) [12] who reported that out-planting survival improved significantly in response to nitrogen application. Sood (1999) [22] reported the increase in survival of *Albizia chinensis* to the nursery condition.

Sofi (2005) [21] also reported that the maximum plant per cent was recorded in seedlings receiving N_{50}+1.5 t FYM ha^{-1} dose of nitrogen and organic fertilizer.

A perusal of data in Table 01 to 07 indicates that both spacing and fertilization had a significant effect on seedling height increment, seedlings having wider spacing receiving different fertilizer doses exhibited lower height increment as compared to seedlings grown at closer spacing. This may be due to more competition between the seedlings at narrow spacing. These results are in close agreement with the findings of Lal (1993) [8] who observed that the seedlings grown at closer spacing (10 x 10 cm) and receiving nitrogen application at the rate of 80 kg ha^{-1} resulted in maximum height increment in *Ulmus laevigata.*

The maximum plant per cent (72.66%), collar diameter (2.50 mm), dry root weight (0.39 g) and dry shoot weight (0.84 g) was recorded at wider spacing (10 x 10 cm) and receiving N_{50}+1.5 t FYM ha^{-1} dose of organic and inorganic fertilizer (B_4F_5) and the maximum was recorded at narrow spacing under control (B_1F_0). The results were in line with Masoodi (1990) [11] who reported that with the increase in spacing and level of nitrogen, there was a significant increase in the collar diameter of *Acer oblongum.* Lal (1993) [8] observed almost similar results in *Ulmus laevigata* Royle. The high shoot root ratio at wider spacing are similar with the findings of Simpson and David (1989) [19] in Douglas fir seedlings. The increase in

biomass is evident as individual component also registered an increased growth at the same spacing. The increase in plant per cent may be due to less competition for space, moisture, nutrients etc and also the availability of optimal level of nutrients due to application of fertilizers in the form of nitrogen and farm yard manure. The findings are in line with the studies of Singh and Sharma (1984) [20] in *Abies pindrow*, Mahajan (1990) [9] in *Robinia pseudoacacia* and Lal (1993) [8] in *Ulmus laevigata.* Sofi (2005) [21] also reported that except plant height, all the other seedling growth parameters significantly increase with the increase in spacing and level of nitrogen of *Cedrus deodara*

Table 1: Effect of spacings, nitrogen fertilizer and their interaction on plant per cent of *Pinus halepensis* during the year 2009 and 2010 (Average)

Fertilizer / Spacing	Plant per cent								
	F_0	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**Mean**
B_1	45.54 (42.44)	53.17 (46.81)	55.67 (48.25)	56.67 (48.83)	60.41 (51.01)	61.25 (51.50)	59.12 (50.25)	58.08 (49.65)	56.24 (48.59)
B_2	49.75 (44.85)	56.50 (48.73)	58.04 (49.63)	59.12 (50.25)	62.29 (52.12)	63.17 (52.63)	60.96 (51.33)	60.66 (51.15)	58.81 (50.09)
B_3	57.33 (49.21)	59.83 (50.67)	61.75 (51.79)	63.08 (52.58)	69.91 (56.73)	71.33 (57.62)	66.83 (54.83)	64.00 (53.13)	64.26 (53.32)
B_4	60.50 (51.06)	62.66 (52.33)	64.00 (53.13)	65.66 (54.13)	70.16 (56.89)	72.66 (58.48)	69.83 (56.68)	66.83 (54.83)	66.54 (54.69)
Mean	53.28 (46.89)	58.04 (49.64)	59.86 (50.70)	61.13 (51.45)	65.69 (54.19)	67.10 (55.06)	64.18 (53.27)	62.39 (52.19)	

Figures in parenthesis are arc sine transformed values.

CD ($P \leq 0.05$) B = 0.305 F = 0.432 B x F = 0.864

B_1 : 800 seedlings/m^2 (2.5 x 5 cm) F_0 : Control F_4 : N_{50} + 1.0 t FYM ha^{-1}

B_2 : 400 seedlings/m^2 (5 x 5 cm) F_1 : 50 kg N ha^{-1} F_5 : N_{50} + 1.5 t FYM ha^{-1}

B_3 : 200 seedlings/m^2 (5 x 10 cm) F_2 : 100 kg N ha^{-1} F_6 : N_{100} + 1.0 t FYM ha^{-1}

B_4 : 100 seedlings/m^2 (10 x 10 cm) F_3 : 150 kg N ha^{-1} F_7 : N_{100} + 1.5 t FYM ha^{-1}

Table 2: Effect of spacings, nitrogen fertilizer and their interaction on plant height of *Pinus halepensis* during the year 2009 and 2010 (Average)

Fertilizer / Spacing	Plant height (cm)								
	F_0	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**Mean**
B_1	17.81	19.61	20.56	21.58	25.08	27.16	23.25	23.11	**22.27**
B_2	16.25	18.55	18.73	19.91	24.43	25.38	22.03	21.88	**20.89**
B_3	14.60	16.46	16.96	17.08	19.75	21.43	19.30	18.58	**18.02**
B_4	**13.85**	15.06	15.96	16.88	19.16	**20.15**	18.41	18.21	**17.21**
Mean	**15.62**	**17.42**	**18.05**	**18.86**	**22.10**	**23.53**	**20.75**	**20.45**	

CD ($P \leq 0.05$) B = 0.259 F = 0.366 B x F = 0.733

B_1 : 800 seedlings/m^2 (2.5 x 5 cm) F_0 : Control F_4 : N_{50} + 1.0 t FYM ha^{-1}

B_2 : 400 seedlings/m^2 (5 x 5 cm) F_1 : 50 kg N ha^{-1} F_5 : N_{50} + 1.5 t FYM ha^{-1}

B_3 : 200 seedlings/m^2 (5 x 10 cm) F_2 : 100 kg N ha^{-1} F_6 : N_{100} + 1.0 t FYM ha^{-1}

B_4 : 100 seedlings/m^2 (10 x 10 cm) F_3 : 150 kg N ha^{-1} F_7 : N_{100} + 1.5 t FYM ha^{-1}

Table 3: Effect of spacings, nitrogen fertilizer and their interaction on collar diameter of *Pinus halepensis* during the year 2009 and 2010 (Average)

Fertilizer / Spacing	Collar diameter (mm)								
	F_0	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**Mean**
B_1	1.60	1.94	2.06	2.16	2.27	2.34	2.22	2.18	2.10
B_2	1.72	1.95	2.09	2.26	2.32	2.36	2.29	2.28	2.16
B_3	2.05	2.23	2.20	2.29	2.41	2.42	2.33	2.30	2.28
B_4	1.94	2.20	2.21	2.27	2.44	2.50	2.40	2.36	2.29
Mean	1.83	2.08	2.14	2.24	2.36	2.40	2.31	2.28	

CD ($P \leq 0.05$) B = 0.03 F = 0.04 B x F = 0.08

B_1 : 800 seedlings/m^2 (2.5 x 5 cm) F_0 : Control F_4 : N_{50} + 1.0 t FYM ha^{-1}

B_2 : 400 seedlings/m^2 (5 x 5 cm) F_1 : 50 kg N ha^{-1} F_5 : N_{50} + 1.5 t FYM ha^{-1}

B_3 : 200 seedlings/m^2 (5 x 10 cm) F_2 : 100 kg N ha^{-1} F_6 : N_{100} + 1.0 t FYM ha^{-1}

B_4 : 100 seedlings/m^2 (10 x 10 cm) F_3 : 150 kg N ha^{-1} F_7 : N_{100} + 1.5 t FYM ha^{-1}

Table 4: Effect of spacings, nitrogen fertilizer and their interaction on dry root weight of *Pinus halepensis* during the year 2009 and 2010 (Average)

Fertilizer / Spacing	Dry root weight (g)								
	F_0	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**Mean**
B_1	0.21	0.23	0.22	0.24	0.33	0.35	0.30	0.26	**0.26**
B_2	0.20	0.24	0.25	0.27	0.28	0.30	0.27	0.27	**0.26**
B_3	0.24	0.28	0.27	0.29	0.31	0.37	0.31	0.30	**0.29**
B_4	0.23	0.26	0.27	0.29	0.35	0.39	0.33	0.30	**0.30**
Mean	0.22	0.25	0.25	0.27	0.32	0.35	0.30	0.28	

CD ($P \leq 0.05$) B = 0.010 F = 0.014 B x F = 0.028

B_1	:	800 seedlings/m^2 (2.5 x 5 cm)	F_0	:	Control	F_4	:	N_{50} + 1.0 t FYM ha^{-1}
B_2	:	400 seedlings/m^2 (5 x 5 cm)	F_1	:	50 kg N ha^{-1}	F_5	:	N_{50} + 1.5 t FYM ha^{-1}
B_3	:	200 seedlings/m^2 (5 x 10 cm)	F_2	:	100 kg N ha^{-1}	F_6	:	N_{100} + 1.0 t FYM ha^{-1}
B_4	:	100 seedlings/m^2 (10 x 10 cm)	F_3	:	150 kg N ha^{-1}	F_7	:	N_{100} + 1.5 t FYM ha^{-1}

Table 5: Effect of spacings, nitrogen fertilizer and their interaction on dry shoot weight of *Pinus halepensis* during the year 2009 and 2010 (Average)

Fertilizer / Spacing	F_0	F_1	F_2	F_3	F_4	F_5	F_6	F_7	Mean
B_1	0.40	0.42	0.45	0.45	0.61	0.65	0.56	0.53	**0.51**
B_2	0.41	0.50	0.52	0.55	0.65	0.70	0.60	0.56	**0.56**
B_3	0.44	0.50	0.52	0.55	0.65	0.75	0.63	0.60	**0.58**
B_4	0.51	0.55	0.56	0.61	0.71	0.84	0.65	0.61	**0.63**
Mean	0.44	0.49	0.51	0.54	0.65	0.74	0.61	0.58	

CD ($P \leq 0.05$) B = 0.006 F = 0.008 B x F = 0.017

B_1	:	800 seedlings/m^2 (2.5 x 5 cm)	F_0	:	Control	F_4	:	N_{50} + 1.0 t FYM ha^{-1}
B_2	:	400 seedlings/m^2 (5 x 5 cm)	F_1	:	50 kg N ha^{-1}	F_5	:	N_{50} + 1.5 t FYM ha^{-1}
B_3	:	200 seedlings/m^2 (5 x 10 cm)	F_2	:	100 kg N ha^{-1}	F_6	:	N_{100} + 1.0 t FYM ha^{-1}
B_4	:	100 seedlings/m^2 (10 x 10 cm)	F_3	:	150 kg N ha^{-1}	F_7	:	N_{100} + 1.5 t FYM ha^{-1}

Table 6: Effect of spacings, nitrogen fertilizer and their interaction on shoot root ratio of *Pinus halepensis* during the year 2009 and 2010 (Average)

Fertilizer / Spacing	F_0	F_1	F_2	F_3	F_4	F_5	F_6	F_7	Mean
B_1	1.83	1.84	1.86	1.87	2.02	2.09	1.92	1.93	**1.92**
B_2	1.85	1.89	1.92	1.93	2.02	2.13	1.97	1.96	**1.96**
B_3	1.95	2.03	2.04	2.06	2.09	2.13	2.08	2.07	**2.06**
B_4	2.03	2.08	2.09	2.11	2.21	2.27	2.15	2.13	**2.13**
Mean	1.92	1.96	1.98	1.99	2.08	2.16	2.03	2.02	

CD ($P \leq 0.05$) B = 0.034 F = 0.048 B x F = 0.096

B_1	:	800 seedlings/m^2 (2.5 x 5 cm)	F_0	:	Control	F_4	:	N_{50} + 1.0 t FYM ha^{-1}
B_2	:	400 seedlings/m^2 (5 x 5 cm)	F_1	:	50 kg N ha^{-1}	F_5	:	N_{50} + 1.5 t FYM ha^{-1}
B_3	:	200 seedlings/m^2 (5 x 10 cm)	F_2	:	100 kg N ha^{-1}	F_6	:	N_{100} + 1.0 t FYM ha^{-1}
B_4	:	100 seedlings/m^2 (10 x 10 cm)	F_3	:	150 kg N ha^{-1}	F_7	:	N_{100} + 1.5 t FYM ha^{-1}

Table 08: Effect of spacings, nitrogen fertilizer and their interaction on total fresh biomass (g) of *Pinus halepensis* during the year 2009 and 2010 (Average)

Fertilizer / Spacing	F_0	F_1	F_2	F_3	F_4	F_5	F_6	F_7	Mean
B_1	1.78	1.88	2.05	2.03	2.32	2.52	2.21	2.12	2.11
B_2	1.97	2.07	2.12	2.18	2.42	2.72	2.25	2.17	2.23
B_3	1.99	2.13	2.16	2.20	2.72	3.08	2.50	2.43	2.40
B_4	2.10	2.16	2.26	2.35	3.06	3.18	2.69	2.44	2.53
Mean	1.96	2.06	2.15	2.19	2.63	2.87	2.41	2.29	

CD ($P \leq 0.05$) B = 0.006 F = 0.009 B x F = 0.018

B_1	:	800 seedlings/m^2 (2.5 x 5 cm)	F_0	:	Control	F_4	:	N_{50} + 1.0 t FYM ha^{-1}
B_2	:	400 seedlings/m^2 (5 x 5 cm)	F_1	:	50 kg N ha^{-1}	F_5	:	N_{50} + 1.5 t FYM ha^{-1}
B_3	:	200 seedlings/m^2 (5 x 10 cm)	F_2	:	100 kg N ha^{-1}	F_6	:	N_{100} + 1.0 t FYM ha^{-1}
B_4	:	100 seedlings/m^2 (10 x 10 cm)	F_3	:	150 kg N ha^{-1}	F_7	:	N_{100} + 1.5 t FYM ha^{-1}

Appendix X: Effect of seed bed density, fertilizer doses and their interaction (B x F) on plant per cent and seedling growth parameters of *Pinus halepensis*

Treatment	Plant (%)		Plant height (cm)		Collar diameter (mm)		Dry root weight (g)		Dry shoot weight (g)		Shoot root ratio		Total fresh biomass (g)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Seed bed densities (B)														
B_1	54.15 (47.38)	58.32 (49.81)	20.13	24.41	2.01	2.18	0.24	0.29	0.45	0.56	1.87	1.72	2.01	2.21
B_2	56.29 (48.62)	61.33 (51.58)	19.02	22.77	2.06	2.25	0.23	0.28	0.50	0.62	1.94	1.97	2.16	2.31
B_3	61.29 (51.55)	67.22 (55.14)	17.03	19.00	2.23	2.33	0.27	0.32	0.53	0.63	2.02	2.07	2.28	2.55
B_4	64.08 (53.19)	69.00 (56.22)	15.57	18.85	2.22	2.36	0.27	0.33	0.56	0.70	2.10	2.16	2.34	2.71
C.D. 0.05	0.443	0.378	0.322	0.259	0.047	0.027	0.011	0.014	0.008	0.008	0.028	0.040	0.009	0.009
Fertilizer doses (F)														

F_0	51.83 (46.05)	54.72 (47.73)	14.82	16.43	1.68	1.97	0.20	0.23	0.41	0.46	1.86	1.96	1.92	1.99
F_1	56.85 (48.95)	59.22 (50.33)	16.43	18.41	2.01	2.14	0.23	0.27	0.45	0.53	1.90	2.02	1.99	2.12
F_2	57.75 (49.46)	61.99 (51.95)	16.88	19.23	2.07	2.20	0.23	0.27	0.45	0.57	1.68	2.01	2.08	2.21
F_3	59.06 (50.23)	63.20 (52.68)	17.40	20.33	2.17	2.31	0.24	0.29	0.48	0.59	2.02	1.96	2.12	2.25
F_4	62.27 (52.13)	69.12 (56.29)	20.10	24.10	2.32	2.40	0.29	0.34	0.57	0.73	2.09	2.07	2.42	2.82
F_5	63.02 (52.59)	71.18 (57.60)	21.23	25.83	2.36	2.44	0.30	0.40	0.64	0.83	2.10	2.19	2.67	3.08
F_6	61.37 (51.60)	67.00 (54.99)	18.41	23.08	2.21	2.40	0.26	0.33	0.53	0.68	2.04	2.01	2.23	2.58

Appendix X

F_7	59.47 (50.47)	65.31 (53.95)	18.23	22.66	2.19	2.36	0.25	0.31	0.50	0.64	1.93	2.10	2.14	2.43
C.D. 0.05	0.627	0.535	0.456	0.567	0.067	0.038	0.016	0.020	0.012	0.011	0.039	0.057	0.013	0.013
Treatment interaction (B x F)														
B_1F_0	44.50 (41.48)	46.58 (43.04)	17.00	18.63	1.43	1.77	0.20	0.22	0.34	0.44	1.72	1.93	1.72	1.82
B_1F_1	52.58 (40.48)	53.75 (47.15)	18.00	21.23	1.85	2.02	0.21	0.24	0.38	0.46	1.72	1.97	1.79	1.96
B_1F_2	53.66 (47.10)	57.66 (49.41)	18.13	23.00	1.95	2.16	0.20	0.24	0.41	0.49	1.76	1.96	1.97	2.11
B_1F_3	54.41 (47.53)	58.91 (50.13)	19.66	23.50	2.07	2.25	0.22	0.25	0.39	0.51	1.81	1.93	1.93	2.12
B_1F_4	56.75 (48.88)	64.08 (53.18)	22.50	27.66	2.23	2.31	0.30	0.35	0.53	0.68	2.01	2.02	2.20	2.43
B_1F_5	56.16 (48.54)	66.33 (54.53)	25.43	28.90	2.30	2.37	0.29	0.39	0.61	0.68	2.08	2.10	2.37	2.67
B_1F_6	58.33 (49.79)	59.91 (50.72)	20.16	26.33	2.14	2.331	0.26	0.33	0.47	0.65	2.10	1.74	2.03	2.37
B_1F_7	56.83 (48.92)	59.33 (50.38)	20.16	26.06	2.09	2.26	0.23	0.27	0.48	0.58	1.81	2.04	2.04	2.19
B_2F_0	48.16 (43.94)	51.33 (45.76)	15.16	17.33	1.48	1.96	0.17	0.22	0.39	0.43	1.88	1.82	1.95	1.98
B_2F_1	56.00 (47.87)	58.00 (49.60)	17.50	19.60	1.91	1.99	0.23	0.24	0.46	0.54	1.81	1.98	2.02	2.11
B_2F_2	56.83 (48.92)	59.25 (50.33)	17.96	19.50	2.04	2.12	0.23	0.27	0.48	0.57	1.84	1.99	2.09	2.13
B_2F_3	58.33 (49.79)	59.91 (50.72)	18.00	21.83	2.14	2.38	0.24	0.29	0.51	0.59	1.94	1.93	2.15	2.20
B_2F_4	58.66 (49.99)	65.91 (54.28)	22.10	26.76	2.24	2.39	0.25	0.32	0.56	0.74	1.98	2.06	2.27	2.55

Appendix X

B_2F_5	59.08 (50.23)	67.25 (55.09)	22.76	28.00	2.31	2.39	0.27	0.33	0.59	0.81	2.18	2.07	2.53	2.91
B_2F_6	56.50 (48.73)	65.41 (53.98)	19.33	24.73	2.16	2.42	0.23	0.31	0.53	0.66	2.00	1.94	2.19	2.29
B_2F_7	57.75 (49.45)	63.58 (52.88)	19.33	24.43	2.17	2.39	0.25	0.29	0.47	0.65	1.92	1.98	2.06	2.28
B_3F_0	56.00 (48.44)	58.66 (49.99)	13.66	15.53	2.02	2.08	0.23	0.25	0.43	0.45	2.01	1.89	1.96	2.01
B_3F_1	58.16 (49.70)	61.50 (51.64)	15.86	17.06	2.19	2.27	0.26	0.31	0.45	0.53	2.04	2.02	2.03	2.23
B_3F_2	58.16 (49.70)	65.33 (53.93)	16.33	17.60	2.14	2.26	0.24	0.30	0.44	0.59	2.00	2.06	2.06	2.25
B_3F_3	59.83 (50.67)	66.33 (54.53)	16.16	18.00	2.24	2.33	0.27	0.30	0.47	0.63	2.09	2.03	2.12	2.28
B_3F_4	66.66 (54.73)	73.16 (58.80)	19.16	20.33	2.41	2.39	0.30	0.30	0.59	0.71	2.06	2.11	2.51	2.92
B_3F_5	67.83 (55.44)	74.83 (59.89)	19.43	23.43	2.42	2.42	0.32	0.41	0.65	0.86	1.93	2.31	2.90	3.26
B_3F_6	63.66 (52.93)	70.00 (56.79)	18.16	20.43	2.20	2.45	0.28	0.32	0.59	0.68	2.07	2.08	2.46	2.53
B_3F_7	60.00 (50.77)	68.00 (55.55)	17.50	19.66	2.19	2.41	0.24	0.35	0.56	0.64	2.02	2.13	2.21	2.64
B_4F_0	58.66 (49.99)	62.33 (52.14)	13.46	14.23	1.81	2.08	0.22	0.23	0.48	0.53	1.85	2.21	2.04	2.15
B_4F_1	61.66 (51.74)	63.66 (52.93)	14.36	15.76	2.11	2.29	0.24	0.29	0.52	0.58	2.05	2.11	2.13	2.19
B_4F_2	62.33 (52.14)	65.66 (54.13)	15.10	16.83	2.14	2.27	0.24	0.29	0.49	0.62	2.15	2.03	2.18	2.33
B_4F_3	63.66 (52.93)	67.66 (55.34)	15.76	18.00	2.24	2.29	0.26	0.31	0.57	0.64	2.25	1.96	2.30	2.39

B_4F_4	67.00 (54.93)	73.33 (58.91)	16.66	21.66	2.38	2.51	0.31	0.39	0.61	0.81	2.31	2.10	2.71	2.41
B_4F_5	69.00 (56.16)	76.33 (60.89)	17.30	23.00	2.40	2.59	0.32	0.46	0.71	0.96	2.24	2.31	2.86	3.49
B_4F_6	67.00 (54.94)	72.66 (58.48)	16.00	20.83	2.34	2.45	0.29	0.37	0.55	0.74	2.00	2.30	2.25	3.12
B_4F_7	63.33 (52.73)	70.33 (56.99)	15.93	20.50	2.32	2.39	0.28	0.32	0.51	0.72	1.97	2.28	2.27	2.62
C.D. 0.05	1.254	1.070	0.912	1.134	0.134	0.076	0.032	0.041	0.023	0.017	0.079	0.115	0.026	0.027

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