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Increment Characteristics for Man-Made Stand of Norway Spruce (*Picea abies* L. Karst) in North of Iran

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Abstract: In this study, the afforestation stands of 18.1 ha with planting interval 2×2 m of *Picea abies*, at the age of 44 years old was investigated to compute increment and wood production in Kelardasht plantation (North of Iran). This stand was inventoried using region map and 70×70 m inventory grid. The samples were taken by randomized-systematic method. Increment statistical factors in 32 sample plots with 500 m^2 area were measured. Inside each plot, Diameter at Breast Height (DBH) of whole trees and height of four witness trees (two thickness trees inside the plot and two nearest trees to center of plot) were measured. Results of this research showed that survival percentage of *Picea abies* at the age of 44 years old was 39.3% in Kelardasht region. Also, the average of stand diameter, height, basal area, volume, annual volume increment and form factor were 16.86 cm, 18.20 m, 23.59 m^2 ha^{-1}, 193.73 m^3 ha^{-1}, 4.4 m^3/ha/year and 0.46, respectively. Considering obtaining results and comparing them with its main habitat, the stand increment amount and statistical parameters are low.

Key words: *Picea abies* L. Krast, increment, form factor

INTRODUCTION

Pay attention to, the most species of Iran North forests have low increment, need to woods with tall wood elements (fiber and tracheid) in woody industries and also considering to establishment of forgery big industries in world thus, need to afforestation is increasing day to day. It is look that plantation of species with high increment is able to answering to these needs. With considering, plantation of native species are proposed always, but sometimes because of economical reasons, higher increment and ensuring of appropriate wood for marketing, it is possible to plantation of exotic species (Rezayee, 1995; Khodabakhsh, 1998).

We should culture the species with high increment by arboriculture programming for its utilization in industrial poles. In these conditions conservation of existence species are necessary and plantation with exotic species is proposed by Mosadegh (1996). Investigation of afforestation successfully with *Picea abie*s in plant community of Kelardasht region showed that the parcel with number 4 and with fertility index of 26 is the best site. This species in this habitat with production of 120 m^3 ha^{-1} and age of 25 years old is similar to the best site of *Picea abies* in European (Mirbadin and Sagheb, 1991).

Pormajidain (1992) investigated increment characteristics for *Picea abies* in Kelardasht region (North of Iran) by randomized-systematic method with considering age of 29 years old and diameter mean of 11.05. Results his research showed that the diameter, height, volume increment average were 0.38 cm, 0.32 m and 1.56 m^3 ha^{-1}, respectively. Rezayee (1995) surveyed *Picea abies* afforestation stand in age of 35 years old in Lajim region (North of Iran) with plantation distance 2×2 m using random-systematically method. He was resulted that volume, basal area, height and diameter increment average were 4.3 m^3/ha/year, 0.4 m^2 ha^{-1}, 0.4 m and 0.5 cm, respectively.

Johnssson (1995) investigated the *Picea abies* stands situated in 55° to 66° latitude and mean age of 41 years old. Results of his research showed that mean of stand density and diameter is 1640 ha^{-1} and 25 cm, respectively. Also, it is resulted that viability percentage of *Picea abies* young stands are less in heavy clay soils in compare to the other soil types. The institute of forests and rangelands researches in Iran studied the efforestation successfully of *Picea abies* stand in Kelardasht region. The obtained report is indicating adaptation of this species with its site (Khodabakhsh, 1998). Gorjy and Gholy (1997) investigated this species

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in Sangdeh region of Mazandaran province (North of Iran). Their research showed that *Picea abies* with provenance of Yugoslavian is adapted with site conditions and viability of this species is 95%.

Siahipoor *et al*. (2000) studied the afforestation 23 years old of *Picea abies* with plantation distance 2×2 m in Asalem region (North of Iran). The mean of diameter, height, basal area and mean of annual volume increment were recorded 14 cm, 10.5 m, 34.3 m^3 ha^{-1} and 7.5 silve ha^{-1}, respectively. Misson *et al*. (2002) showed that stand density can change the relation between climate and increment as in single trees; the thinning can increase resistance of tree opposite to drought. Makinen *et al*. (2002a) mentioned that thinning is due to increasing of radial increment in low sections of tree stem in compare to higher heights.

Makinen *et al*. (2002b) investigated the changes of radial increment for *Picea abies* in different latitudes and altitudes in north and center of European. Results of theirs research showed that increment changes in 10 years periods were similar in every site, but had significant different in different sites. Jaakola *et al*. (2006) studied the *Picea abies* stand in Finland. Results of his research showed that thinning operations increased the speed of single tree increment but special weight was reduced. Increasing speed of increment is possible to reduce of tracheid length and size of fibers is affected, also. Parn (2006) resulted that climate changes has significant effects on radial increment but pollutions have low effects on radial increment of *Picea abies* stand.

Raiskila *et al*. (2006) studied the characteristics of wood in *Picea abies* species. They reported the mean of annual ring cross about 2.76±1.07 to 3.70±1.22 mm. Mean of special weight in *Picea abies* wood was 461±0.077 g cm^3, also. Zangrele and Oberhuber (2007) studied the changes of radial increment in *Picea* species. They resulted that felling of aside dominant trees, is due to improvement of tree radial increment. Investigation and growth study and operation of *Picea abies* afforestation stand and its comparison with origin sites of this species and performed afforestations can be an appropriate field for the better management of aforementioned afforestations. This research was investigated the increment characteristics of *Picea abies* including diameter, height, basal area and volume in Kelardasht region (North of Iran) and obtained results will compare to results some of other regions.

MATERIALS AND METHODS

Study area: Study area (18.1 ha^{-1} areas) was afforestation with *Picea abies* (L.) in 1965 by Total Official of Natural Resources-Noushahr (TONRN) (North of Iran) with initial plantation distance of 2×2 m. These areas are situated in forest management plan of Marzan Abad. Study area is located on 45 km southwest far from Chalous town (Kelardasht region) between 36° 29' 54" to 36° 29' 52" North latitude and 51° 10' 51" to 51° 10' 00" East longitude. The general aspects of these forests are Northern. The average slope of forest field is about 15% (Min. 5% and Max. 27%), the height of forest area at sea level starts from 1250 m and continues till about 1350 m (Mohammadpoor, 2007). This research was performed in the summer of 2006.

Sampling method: Pay attention to evenness of stand and facility in performance, randomized-systematic method was used for accomplishment of this research. Area of sample plots with considering at least 10-15 trees in every sample plot (Zobeiry, 2000) were selected 500 m^2 with circle form. Numbers of 32 sample plots with grid dimensions of 70×70 m were designed and inventory intensity was 10.2% in this study that was sufficient pay attention to obtained results by Pormajidian (1992), Keshavars (1992), Khodabakhsh (1998) and Haghi (2002). In every sample plots, diameter at breast high whole trees using caliper and height of witness four trees (two largest diameter and two nearest to center of sample plots) and totally, height of 128 witness trees in whole areas were recorded by means of suunto clinometer's.

Investigation normality of *Picea abies* stand: Normality distribution is defined by probability density function (Eq. 1) (Zobeiry, 2000).

$$f(x) = \frac{N \times d}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left[\frac{x-\mu}{\sigma}\right]^2} \quad (1)$$

Where:

- μ = Real mean of community
- σ = Standard deviation
- x = Quantity that calculating of its frequencies is considerable
- e = Natural logarithm, that is equal to 2.7183
- N = Total No. of community members

Pearson coefficient was used for calculation of skewness (Eq. 2, 3) (Zobeiry, 2000; Rahimnejad, 2002).

$$b = \frac{3(\bar{X} - M_d)}{S_x} \quad (2)$$

$$M_d = L + \frac{\frac{n}{2} - fc}{f_i} \times C \quad (3)$$

Where:

- b = Pearson skewness coefficient
- $\bar{X}$ = Community mean
- M_d = Medium
- S_x = Standard deviation
- L = Low limit of class that medium is situated in it
- n = No. of data
- fc = Density frequency before class that medium is situated in it
- f_i = Unconditional frequency of class that medium is situated in it
- C = Class cross

Calculation of form factor and stand kurtoisis: Form factor and kurtoisis were calculated using Eq. 4 and 5 (Namiranian, 1991; Zobeiry, 2000).

$$F_n = \frac{\bar{h}}{\bar{d}} \times 100 \quad (4)$$

$$f = \frac{V}{\frac{\pi}{4} \times d_{1.3}^2 \times h} = \frac{V}{g_{1.3} \times h} \quad (5)$$

Where:

- F_n = Kurtoisis coefficient of stand
- $\bar{h}$ = Average of height (m)
- $\bar{d}$ = Average of diameter at breast height (cm)
- f = Form factor of tree
- V = Tree volume (m^3)
- h = Height of tree (m)
- g = Basal area at breast height (m^2)

RESULTS

Distribution number per hectare and stand normality: The diagram of number distribution in diameter classes and normal curve showed that studied stand has even aged structure (Fig. 1) and probability density function is as below:

$$f(x) = 212.39 \times e - \frac{(d_i - 16.86)^2}{26.94}$$

For confidence normality and abnormality of stand distribution, Chi-square test was used which calculated 34.601 for this stand. Pay attention to Chi-square test of table at level of 5% and degree freedom 8 (equal to 15.507), the supposition of different between numbers per hectare of *Picea abies* stand in Kelardasht with normal distribution are significant. Pearson coefficient for

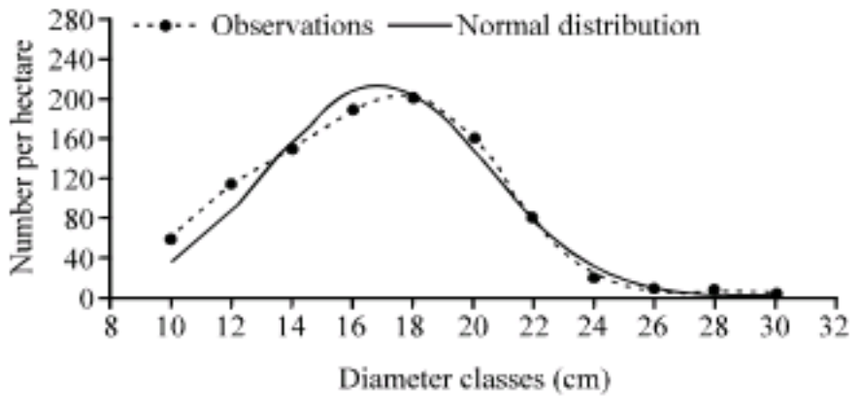

Fig. 1: The normal curve of number distribution per hectare for *Picea abies* stand

Table 1: Statistical characteristics for *Picea abies* in Kelardasht region at 44 years old

Statistical characteristics	Mean±SD	SE	CV (%)	Annual increment average
Number per hectare	982.00±38.8	13.90	3.95	-
Diameter (cm)	16.86±3.67	0.22	21.76	0.38
Height (m)	18.20±1.98	0.35	10.89	0.41
Basal area (m^2 ha^{-1})	23.59±1.10	0.11	4.66	0.54
Volume (m^3 ha^{-1})	193.73±9.20	0.99	4.79	4.40

distribution number per hectare of stand on basis of diameter classes was calculated −0.76. Aforementioned stand has 982 No. ha^{-1} and considering initialing plantation distance 2×2 m and number of initial plantation 2500 No. ha^{-1}, natural mortality, cultural inventions, disallowable felling, disease and pests, the viability percentage was 39.3%.

$$b = \frac{3(16.86 - 17.79)}{3.67} = -0.76, \qquad M_d = 16 + (0.898 \times 2) = 17.79 \text{ cm}$$

Diameter, height, basal area and volume increment mean: In even aged stand that diagram of stand trees distribution in diameter classes is near to normal status, the arithmetic mean of diameter and height are used. Diameter mean, diameter average increment, arithmetic mean of height, average increment of height, mean of basal area, average increment of basal area, growing stock, average increment of volume were calculated 16.86, 0.38 cm, 18.20, 0.41 m, 23.59 m^2 ha^{-1}, 0.54 m^2/ha/year, 193.73 m^3 ha^{-1} and 4.4 m^3/ha/year, respectively (Table 1).

Form factor and kurtoisis of stand: Forma factor calculated 0.46 for *Picea abies* stand. Also, statistical characteristics including standard deviation, standard error and coefficient variance (%) for form factor of *Picea abies* were calculated 0.03, 0.01 and 6.5%, respectively. Kurtoisis coefficient is one of the most factors that are used for judgment in relation to stand stability. This coefficient was 107.95% for studied stand (Fig. 2).

DISCUSSION

Distribution number per hectare and stand normality: The curve of number per hectare in different diameter classes (Fig. 1) showed that investigated stand has even aged structure. Chi-square test showed that the curve of number per hectare is not similar to normal distribution curve. Skewness of stand is high, also (Rahimnejad, 2002). Number per hectare was more than normal status at diameter classes of 12-14 cm that should be considered in cultural operations. Viability percentage and number per hectare of *Picea abies* stand were compared pay attention to this study and the other performed studies (Table 2). Table 2 showed that *Picea abies* stand of Kelardasht region has viability percentage and number per hectare more appropriate with considering to stand age in compare to the other mentioned sites.

Diameter, height, basal area and volume increment average: Pay attention to performed studies (Mirbadin and Sagheb, 1991; Pormajidian, 1991; Rezayee, 1995; Siahipoor *et al*., 2000; Dohrenbusch *et al*., 2002; Siahipoor *et al*., 2002), it is mentionable that diameter increment of this stand had not high changes from 29 years old up to now. Also, diameter increment average is lower than sites with three grades of French (Table 3). Because of number per hectare of low diameter classes are high in stand, therefore, trees have competitive status one another and the stand has higher height increment in compare to diameter increment.

For improvement of stand diameter increment, harvesting of low diameter classes should be considered in programming of cultural operation in order to increasing of stand diameter increment. Also, with considering Table 3, it is clear that height increment average of stand is equal to French sites, relatively. Because of existence high density and increasing of competition in stand, the diameter increment is reduced and height increment will increase, thus, stand stability will decrease.

Basal area increment of stand are lower than to the other sites similar to diameter increment because of high density of low diameter class in stand (Table 3), which is due to reduction of diameter, basal area and volume increments. Pay attention to performed studies (Assman, 1961; Pormajidian, 1991; Rezayee, 1995; Dohrenbusch *et al*., 2002; Siahipoor *et al*., 2002), it is considerable that volume increment of stand was lower than to different sites in Iran and out of Iran and also has lower growing stock (Table 4) and performing of appropriate culture operations is necessary for its enhance.

In order to increase of production in area unit and improvement of quantity and quality characteristics of *Picea abies* afforestation in Kelardasht region, the operation of thinning should be performed with high precession pay attention to site typical conditions, high kurtoisis coefficient and skewness coefficient of stand. Because of, every intervention without consideration to stand conditions is due to reduction of tree resistance opposite to environmental parameters such as wind and snow, etc. and it is increased fall of stand trees by wind.

Form factor and kurtoisis of stand: Form factor of stand is depending to some of factors such as age, site and species, even aged or uneven aged of stand and cultural method of forest. Also, form factor is more in young stands and lower in stands with high ages (Zobeiry, 2000). Form factor mean of *Picea abies* stand in Kelardasht region calculated 0.46 that is appropriate, almost with considering the low age of stand. Stability coefficient was calculated 107.95% for *Picea abies* stand in Kelardasht stand at age of 44 years old, therefore, the stand sorted in very instability class (Namiranian, 1991).

The curve of stability coefficient on basis of diameter classes is showing that stability coefficient has descending status and the stability of stand will increase

Table 2: Comparison of viability percentage of *Picea abies* in different regions

Site	Stand age	Number per hectare	Viability (%)	References
Kelardasht (Iran)	25	2375	95.0	Mirbadin and Sagheb (1991)
Lajim (Iran)	35	625	25.0	Rezayee (1995)
Siahkal (Iran)	17	1173	47.0	Siahipoor *et al*. (2002)
Pisesoon (Iran)	27	1010	40.4	Siahipoor *et al*. (2002)
Kelardasht (Iran)	44	982	39.3	Present research

Table 3: Comparison of diameter, height and basal area increment for *Picea abies* in different regions

Site	Stand age	Diameter Mean±SD (cm)	Diameter increment (cm)	Height Mean±SD (m)	Height increment (m)	Basal area Mean±SD (m^2 ha^{-1})	Basal area increment average ±SD (m^2 ha^{-1})	References
Kelardasht (Iran)	25	12.50±3.21	0.50	10.10±1.25	0.40	30.31±4.78	1.21±0.32	Mirbadin and Talebi (1991)
Kelardasht (Iran)	29	11.02±2.41	0.38	9.15±2.15	0.32	-	-	Pormajidian (1992)
Lajim (Iran)	35	17.50±3.14	0.50	14.20±3.65	0.40	14.00±3.26	0.40±0.10	Rezayee (1995)
Germany	65	26.65±4.56	0.41	19.50±2.34	0.30	-	-	Dohrenbusch *et al*. (2002)
Siahkal of Guilan (Iran)	17	10.20±1.25	0.60	8.60±3.26	0.50	13.30±4.25	0.78±0.12	Siahipoor *et al*. (2002)
Pisesoon of Guilan (Iran)	27	17.01±4.10	0.63	14.10±4.17	0.49	23.50±5.65	0.87±0.11	Siahipoor *et al*. (2002)
Kelardasht (Iran)	44	16.86±3.15	0.38	18.20±4.10	0.41	23.59±6.25	0.54±0.03	Present research

Table 4: Comparison of volume increment for *Picea abies* in different regions

Site	Age	Volume Mean±SD (m^3 ha^{-1})	Volume increment average ±SD (m^3 ha^{-1})	References
Germany	30	183.00±11.21	6.1±1.21	Assman (1961)
Germany	20	74.00±8.16	3.7±1.04	Assman (1961)
Germany	40	308.00±11.21	7.7±1.50	Assman (1961)
Germany	10	12.00±1.26	1.2±0.65	Assman (1961)
Germany	50	435.00±14.25	8.7±1.54	Assman (1961)
Germany	60	552.00±11.32	9.2±1.65	Assman (1961)
Germany	70	653.00±12.35	9.33±0.89	Assman (1961)
Germany	80	740.00±11.56	9.25±1.32	Assman (1961)
Kelardasht (Iran)	29	45.26±10.01	1.4±0.56	Pormajidian (1991)
Lajim (Iran)	35	227.50±9.69	6.5±0.89	Rezayee (1995)
Germany	65	585.00±8.95	9.0±0.97	Dorhenbusch *et al*. (2002)
Rik (Iran)	27	184.40±11.26	6.8±1.24	Siahipoor *et al*. (2002)
Oroston (Iran)	27	301.30±10.29	11.2±2.12	Siahipoor *et al*. 2002
Siahkal (Iran)	17	68.80±9.89	4.1±1.36	Siahipoor *et al*. (2002)
Pisesoon (Iran)	27	238.20±8.98	8.8±1.10	Siahipoor *et al*. (2002)
Kelardasht (Iran)	44	193.73±9.97	4.4±1.25	Present research

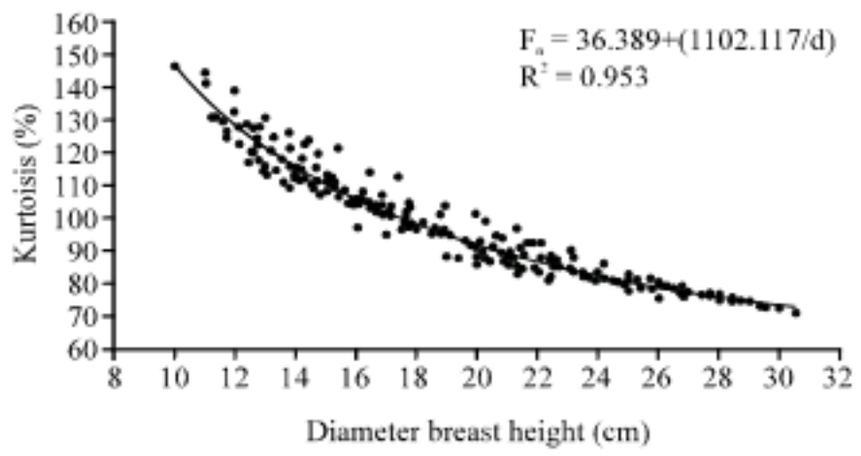

Fig. 2: Scatter plot and the curve of stand kurtoisis

with increasing of diameter (Fig. 2). High kurtoisis coefficient of this stand is due to stand density, competition between species for achievement to light and laying in high stair and do not thinning of stand in appropriate time. With appropriate cultural operation and thinning of stand, it is possible to reduce this coefficient but, thinning operation should be performed with high precession because of stand is very instability and pay attention to superficial roots of *Picea abies* species, the danger of fall by wind is very high in stand. Siahipoor *et al*. (2002) estimated the stability coefficient for *Picea abies* at 27 years old about 89 and 78% for Oroston and Pisesoon regions (North of Iran), respectively. Therefore, Oroston Picea stand and Pisesoon Picea stand are sorted in instability and stability classes, respectively.

CONCLUSION

Mean number per hectare of *Picea abies* in study area was 982 and almost 60% of initial planted sapling were deleted by reason of competition, primary harvesting and the other environmental factors such as snow, wind and disallowable felling and the stand missed its normal status and has high density in low diameter classes. Mean of diameter, height, basal area and volume increments in study area and its compare with the other sites is indicating low increment and yield in stand. Probably, low increment in surveyed stand is due to disallowable felling and do not performing of appropriate cultural operations in stand that is due to stand distance of normal status.

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