NATURAL REGENERATION OF SILVER FIR (*ABIES PINDROW*) IN THE MOIST TEMPERATE FOREST OF PAKISTAN (A CASE STUDY FROM KUND)

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ABSTRACT

Experiments were conducted to study microclimate and natural regeneration of *Abies pindrow* in the moist temperate forests of Pakistan at Kund. It has been concluded that tree and vegetative cover from *Viburnm* and *Tree plus Viburnm* greatly affects the PAR levels reaching seedlings. Under these conditions, the quantity of PAR reaching at seedlings height was reduced to 2-4% of total PAR received in the open conditions.

After seeds germinate, mortality rates of 1 to 3 year old seedlings are high. The mortality rate of 1, 2 and 3 year old seedlings observed after 3 years were 88, 60 and 70% in open while 79, 82 and 69% in shade respectively. Survival rate of 4 to 7 years old seedlings is less affected in the open. Height growth is slow, only 4.7 cm observed over three years (1.6 cm/year) in 7 years old seedlings, is normal for many species of Abies. This paper discusses the effects of vegetation cover ground conditions and grazing on the establishment and survival of the natural regeneration.

INTRODUCTION

The importance of fir (*Abies pindrow*) as a timber species in Pakistan is well documented (Khan, 1979; Sheikh and Hafeez, 1975; Troup, 1921). *Abies pindrow* forests cover 45 percent of the productive coniferous forest area of Pakistan (Amjad and Khan, 1989) and due to its suitability for pulpwood as well as for other traditional uses, its economic importance is increasing (Bakshi *et al*. 1972; Datta, 1958; Kaushik, 1954; Khan, 1979; Singh and Singh, 1984). On a regional scale fir forests play a key role in the protection of watersheds and fragile mountain ecosystems, by preventing soil erosion as well as floods and droughts in the plains. In addition, fir forests cater to the needs of local populations for fuel wood and provide grazing grounds for large herds of cattle, sheep and goats during the summer (Sheikh, 1985). Grazing pressures, inadequate management of the existing forest lands and poor natural regeneration have led to the rapid depletion of these forests (Bakshi *et al*. 1972; Kaushik, 1954; Khattak, 1970; Singh and Singh, 1984). This paper discusses the effects of vegetation cover, ground conditions and grazing on the establishment and survival of the natural regeneration.

Factors affecting natural regeneration

Natural regeneration of silver fir in the North-Western Himalayas continues to be a problem since ages. At many sites soil moisture is likely to become increasingly deficient from snow melt to the start of the monsoon. Droughts in June, due to a late monsoon, can be especially harmful for the establishment of tender seedlings. Competition for light becomes more important in the monsoon from July to September each year when the surrounding ground vegetation grows vigorously and soil water is less limiting. Root competition for moisture and nutrients, however, may still be important. The following factors are considered responsible for the lack of natural regeneration is silver fir forests.

i. Seed production:

Moderately good seed production can be expected every three or four years, though it has been postulated by Dhillon (1961); Khan (1979); and Singh (1961) that it may be inadequate for natural regeneration since the advanced age of the mother trees results in low seed viability.

ii. Litter and humus:

Young seedlings may fail to establish themselves because the thick humus layers prevent their roots from reaching the mineral soil beneath. (Ahamd, 1955; Dhillon, 1961; Khan, 1979; Khattak, 1970; Singh, 1961)

iii. Light conditions on the forest floor:

Fir seedlings can tolerate a considerable degree of shade in their early stages. Seedlings continue to grow well with close spacings of the mother trees, but for best growth full overhead light is required. The presence of broadleaved species in silver fir forests improves light conditions due to their spreading crowns and may help natural regeneration. Small gaps of 400 to 500 m^2 in the tree canopy are considered suitable for promoting regeneration. Seeding felling (leaving 50 to 60 mature trees per ha), provides adequate light (Dhillon, 1961; Khan, 1979). However, heavy felling encourages weed growth, which can be an important factor inhibiting seedling establishment by suppressing and killing the seedlings. The amount of light reaching the forest floor plays the most important part in weed growth and so affects the natural regeneration of *Abies pindrow*. Weed control by use of chemicals, and machinery are the main measures which have been suggested for overcoming this problem (Bakshi *et al*. 1972; Datta, 1958; Dhillon, 1961; Glover, 1936; Kaushik, 1954; Singh, 1961; Singh, 1973; Sufi, 1970; Troup, 1921)

iv. Damage by animals:

Grazing by domestic animals causes the death of seedlings by trampling and browsing, though controlled grazing before seedfall can be beneficial by disturbing thick humus layers (Khan, 1979; Khattak and Ahmad, 1979; Singh, 1961). Young seedlings are also often nibbled off by the birds after germination in spring (Dhillon, 1961). According to Khattak (1970), fencing is the only way to control the problem of grazing.

Materials and Methods

Study Area (Kund)

Experiments were carried out in almost pure stands of *Abies pindrow* at Kund (elevation of 2475 m). The experimental area is below a ridge on a steep slope facing north-west. The gradient varies from 21° to 46°. The trees are mature and over mature with a mean diameter of 76 cm (standard deviation - SD = $\pm$ 26.5 cm) and a mean height 36 m (SD = $\pm$ 12.1 m). Out of 122 trees 80 percent are *Abies pindrow* and the remaining 20 percent are *Picea smithiana*, *Pinus wallichiana*, *Cedrus deodara* and *Juglans regia*. The main shrub is *Viburnum nervosum*. These stands of mature trees typically have little natural regeneration.

The annual rainfall is in excess of 1700 mm and is concentrated during the monsoon from July to September. The coldest months are December to April when the areas are under snow. June is the hottest month with a maximum mean temperature of 22°C. The growing season is from May to September. There is heavy grazing pressure by local domestic animals and by sheep and goats during migrations to and from summer pastures.

EXPERIMENTAL LAYOUT

The experiment was laidout in R.F. Panjul, Compartment No.11 (Kund) during 1987 over an area of 1.12 hectare (1.12 ha). Half of the experimental area was fenced in order to exclude livestock (cattle, goats and sheep) from the regeneration plots.

MICROCLIMATIC DATA

Microclimatic factors, namely Photosynthetically active radiation (PAR), air temperature and humidity relevant to seedling survival and growth were studied at Kund during 1988 and 1989. Cover conditions in the area were classified into four groups: (a) *Open* (due to canopy gaps); (b) *Tree cover*; (c) *Viburnum cover*; (d) *Trees plus Viburnum cover*. The instruments for the collection of microclimatic data were located in each of the four cover conditions. Photosynthetically active radiation (PAR) was recorded at seedling height in 1988 and 1989, with five Didcot Instruments PAR sensors and E-Cell Integrators (DRP/3). The integrators were read daily to obtain the integrated PAR values for the preceding 24 hrs.

Measurements of temperature and humidity from four cover types were made using ten screened wet and dry bulb thermistors (R.S. Components matched bead type GL 23 thermistors) installed at seedling height. The dry and wet bulb temperature measurements were made daily at 0800, 1300 and 1800 hours and were recorded periodically from July to September.

SURVIVAL OF SEEDLINGS

The natural regeneration of *Abies pindrow* was monitored at the Kund experimental site over a period of three years from 1988 to 1990.

Sampling of area for regeneration

The density and pattern of seedling distribution was studied using three types of sampling units: (i) 0.5 m radius plots; (ii) 1.5 m radius plots and; (iii) 2 m wide and 115 m. long transects (Fig. 1). The ages of seedlings more than one year old were determined as suggested by Troup (1921), by counting the rings of terminal winter bud-scales on the stem.

To eliminate the effect of trampling and grazing, half the experimental area was fenced with wooden posts and barbed wire in June 1987. Half the sampling units were located in the unfenced areas which were open to incidental grazing by domestic livestock. The areas were also subject to the seasonal migration of goats and sheep and the operations of the local grass cutters. A permanent employee was appointed during the day mainly to protect the instruments installed for recording microenvironmental data. Consequently, the local people were quite careful with their cattle, and grazing pressures were not severe.

Initially, in the summer of 1987, 150 plots of 0.5 m radius were laid out in a rectangular grid with cell dimensions 4.7 m x 10 m. In June 1988, 100 more plots of 1.5 m radius were also laid out according to the same design and distance to increase the sampling intensity. In order to determine the effect on germination and distribution of seedlings in relation to topography and tree and ground vegetation cover, four transects (each 2 m wide and 117 m long) were also added to the previous sampling layout.

Survival on each transect was systematically sampled using 20 cm square quadrats positioned every 50 cm during June and July 1988. Each seedling found was numbered and marked for future observations.

Survival, growth and needle numbers for seedlings of different ages located in these sampling units were monitored for three years, from June 1988 to October 1990. Since the effects of fencing were not significant for most of the growth traits, fenced and unfenced data were grouped and results of the seedlings for the whole experiment are described. Moreover, because of the low number of seedlings, and the small increases in their height and needle numbers for different ages, these height and needle increases were analysed with reference to the total number of seedlings per age irrespective of cover condition.

RESULTS

PAR AND TEMPERATURE

The PAR data from May to September for the year 1989 are shown in Table-1.

PAR was 1201 μ mol m^{-2} s^{-1} in the open near F.R.H. during May. It increased to1366 μ mol m^{-2} s^{-1} in June and then decreased to 975, 920 and 524 μ mol m^{-2} s^{-1} during July, August and September respectively.

The *Open* site with seedlings received maximum PAR from May to August while under *Tree cover* the highest value (31 percent) was received in September due to the effect of the west facing aspect and the lower solar elevation interacting with the tree canopies. The *Tree cover* site received the next highest PAR from May to August, *Viburnum* and *Tree plus Viburnum cover* sites received the lowest PAR throughout the growth period.

Survival of seedlings

Seedling numbers and survival rates are shown in Table 2. Since survival is either 0 or 1, the assumption of normality needed for analysis of variance is not satisfied.

Maximum mortality occurred in seedlings up to 3 years of age over a 2 year period in *Open* and shade. Mortality of 4 year old seedlings was

Fig. 1

Distribution of mature *Abies pindrow* and their crown map at Kund.

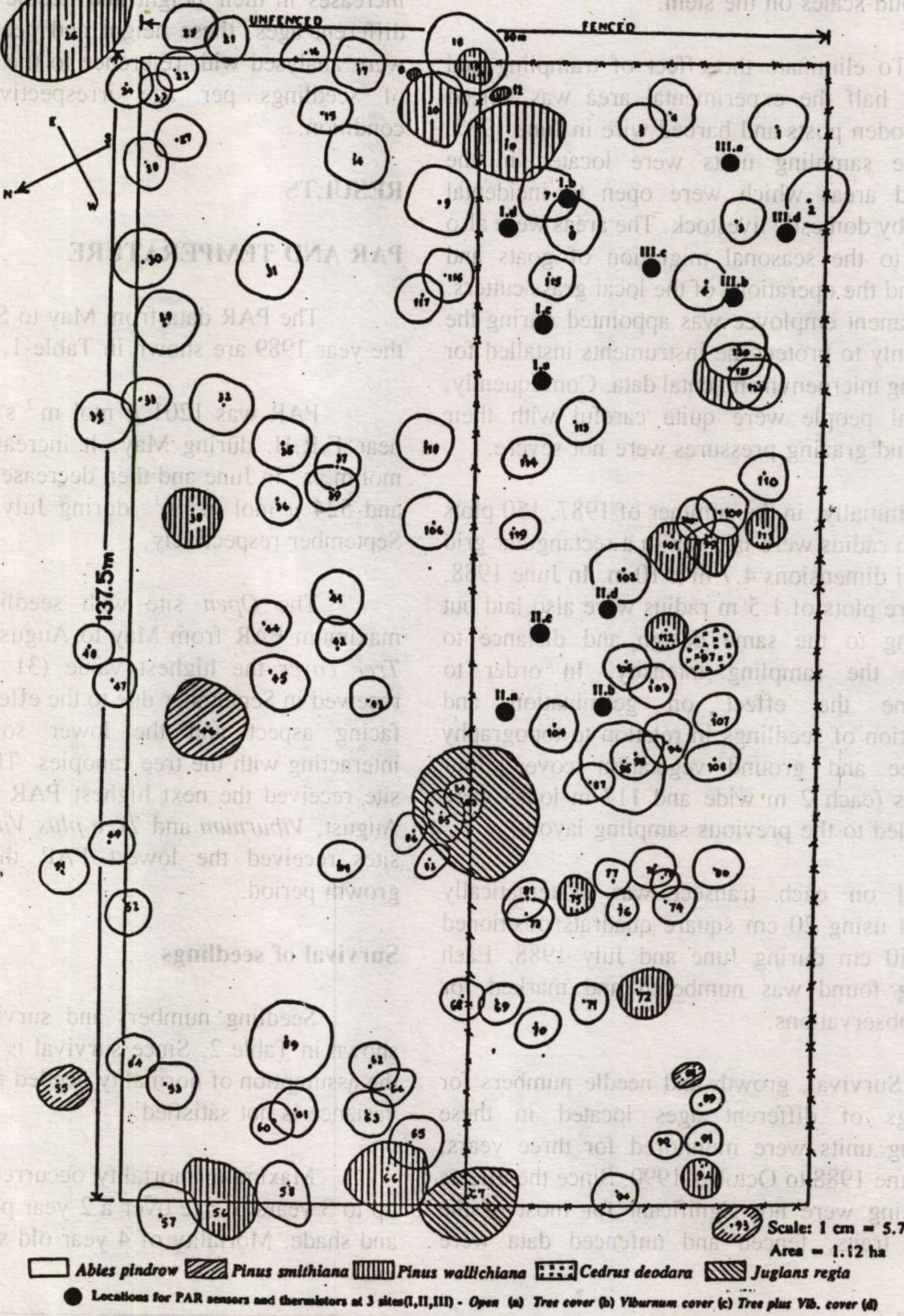
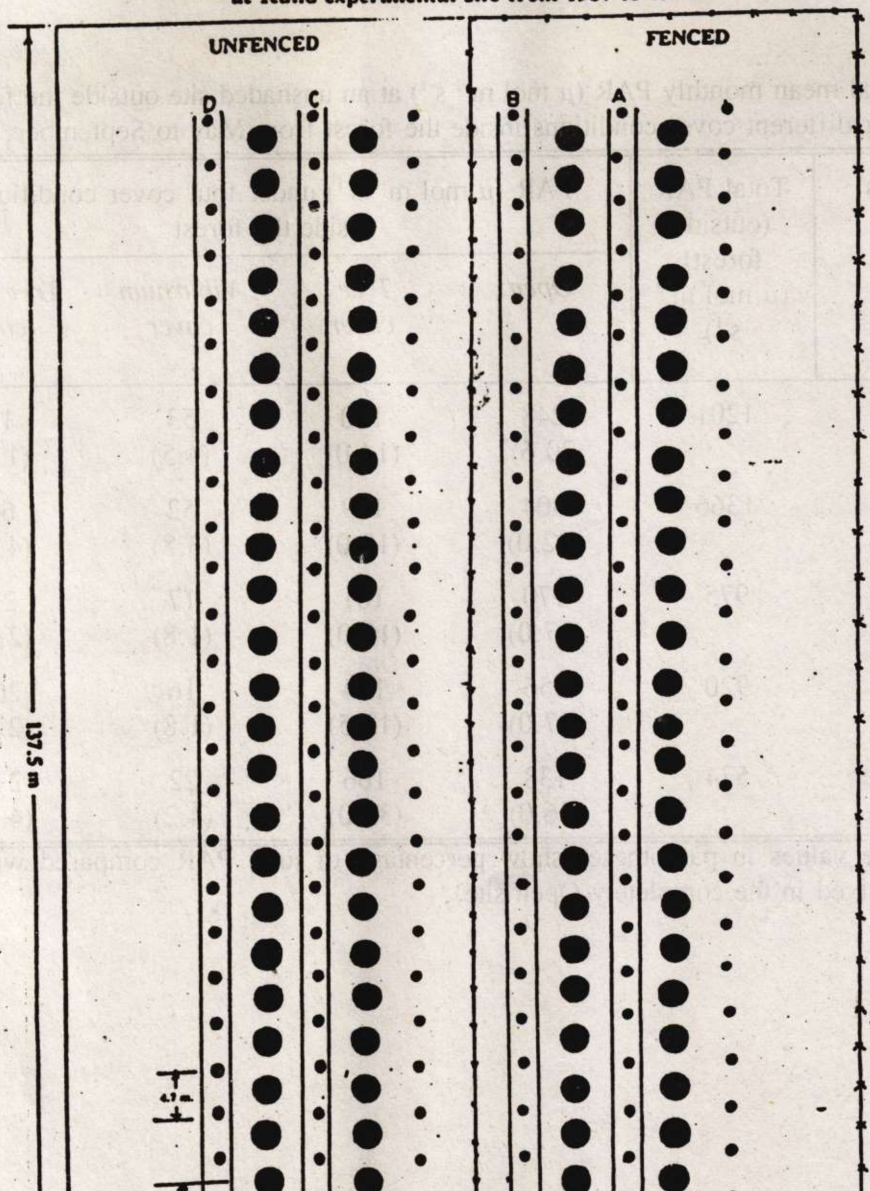


Fig. 2

Sampling systems used to study the natural regeneration of *Abies pindrow* at Kund experimental site from 1987 to 1990.



only observed under shade. The seedlings from 5 to 7 years of age showed no mortality in shade over the two years.

Table 1: Total mean monthly PAR (μ mol m^{-2} s^{-1}) at an unshaded site outside the forest and under four different cover conditions inside the forest from May to September, 1989 at Kund.

Months	Total PAR (outside forest) (μ mol m^{-2} s^{-1})	PAR (μ mol m^{-2} s^{-1}) under four cover conditions inside the forest			
		Open	*Tree cover*	*Viburnum cover*	*Tree+Vib cover*
May	1201	248 (20.6)*	170 (14.0)	53 (4.5)	17 (1.4)
June	1366	304 (22.0)	179 (13.0)	52 (3.8)	64 (4.7)
July	975	170 (17.0)	101 (10.0)	17 (1.8)	27 (2.8)
August	920	156 (17.0)	124 (13.5)	16 (1.8)	26 (2.8)
September	524	138 (26.0)	166 (31.0)	22 (4.2)	21 (4.0)

(The values in parentheses show percentage of total PAR compared with that received in the completely Open site).

Table 2: Survival rate of 1 to 7 year old seedlings recorded during the first assessment in the summer of 1988 and their subsequent survivals in the following two years in the Open and shade at Kund.

Year	Open						
	Age of seedlings in years at initial assessment in 1988						
	1	2	3	4	5	6	7
1988	9	10	10	2	5	0	0
1989	2 (22)*	5 (50)	9 (90)	2 (100)	5 (100)	0	0
1990	2 (22)	4 (40)	3 (30)	2 (100)	5 (100)	0	0
	Shade						
1988	24	45	16	4	8	2	1
1989	10 (41)	19 (42)	9 (56)	4 (100)	8 (100)	2 (100)	1 (100)
1990	5 (21)	8 (18)	5 (31)	2 (50)	8 (100)	2 (100)	1 (100)

* The values in parentheses show the percentage survival of different aged seedlings over two years as there was no recruitment of new seedlings over this period.

The survival of the one year old initial population of seedlings during the second assessment year was greater (41 percent) on shaded sites than on sun-exposed or *Open* sites (22 percent). The survival rate of two year old seedlings over the same period was highest (50 percent) on *Open* sites. Three year old seedlings showed maximum survival (90 percent) in the *Open*, and minimum (56 percent) in the shade.

The survival of the one year old initial population during 1990 showed that one year survival rates were reduced to 21 percent under shade while there were no changes in the *Open*. Mortality continued to increase in two year old seedlings and survival rates of seedlings were lower (only 18 percent) in the shade than in the *Open* (40 percent). There was no mortality of four and five year old seedlings in the *Open* while survival rates of four year old seedlings were reduced to half (50 percent) in the shade. There was no mortality among five to seven years old seedlings. After the end of the third summer, survival rates remained unchanged in both the shaded and unshaded sites.

Height growth of seedlings in relation to age

Mean heights and the increases over three years are shown in Table 3. Height was first monitored in May 1988 (at the start of growth period in 1988). The height increase of the seedlings was significantly affected after 12 months (the end of the 1989 growing season) and 24 months (the end of the growth period in 1990) by the age of the seedlings. This (4.7 cm) increase was greatest for seven year old seedlings and least (1.2 cm) for two year old seedlings. The height increase was significantly affected by seedling age ($p<0.01$).

Table 3 : Mean heights (cm) and height increase over three years from 1988 to 1990.

Years	Mean height and height growth (cm) of seedlings from 1988 to 1990 in relation to age						
	Age in years						
	1	2	3	4	5	6	7
1988	3.4	4.5	6.5	5.9	8.5	10.5	12.3
1990	6.3	5.7	8.5	8.0	11.3	12.7	17.0
Increase over 2 years	2.9	1.2	2.0	2.1	2.6	2.2	4.7

Needle numbers increase in relation to age

The increase in the number of needles over three years is shown in Table 4. The increase was greatest in six to seven year old seedlings (75 and 50 needles respectively) and least (9 needles) for two year old seedlings.

Table 4: Mean initial needle numbers of 1 to 7 years old seedlings and increase over three years from 1988 to 1990.

Years	Mean initial needle numbers and increase from 1988 to 1990 in relation to age						
	Initial age in years						
	1	2	3	4	5	6	7
1988	13	23	37	36	73	110	120
1990	26	32	52	50	115	185	170
Increase over 2 years	13	9	15	14	42	75	50

The needle numbers increased significantly with the age of the seedlings over the period of three years ($p<0.001$). The highest increase was obtained in six year old seedlings. The needle number increase was greater after five years of age. The higher needle numbers provide increase in needle area resulting in greater photosynthetic activity.

DISCUSSIONS

A dense forest canopy drastically modifies the quantity and quality of solar energy incident on the forest floor. The changes in the spectral distribution of daylight that occur in vegetational shade and their effects on plant growth are very important (Kwesiga *et al.* 1986; Evans, 1969). The PAR levels measured at Kund showed that during the growth period from May to September, 1989 *Viburnum* and *Tree plus Viburnum* sites received the least PAR compared with the unshaded site outside the forest. During July and August, the PAR under the *Viburnum* and *Tree plus Viburnum* sites was only 2 to 3 percent of the total incident PAR, indicating the intense shading effect of vegetation cover, while it increased to 4 percent during September with the gradual decrease in the vegetation cover interacting with low sun angle. The reduction in PAR was 3 to 4 times greater at the *Tree cover* site throughout the growth period but was still only 10 to 31 percent of that received in the *Open* site conditions. The daily air temperatures and humidities were gnerally similar in differnet vegetation cover treatments throughout the growing season.

Seedling survival is greatly affected by soil nutrients, light, temperature extremes, soil moisture and biological hazards including livestock grazing, and consumption by rodents and termites during pine establishment periods (Ferguson *et al*, 1955). Few researchers have described the ecological significance of conifer establishment in subalpine forests (Ooesting and Reed, 1952; Whippel and Dix, 1979; Veblen, 1986). Muyicui and Smith (1991) suggest that seed abundance is not a primary factor in successful seedling establishment of *Abies lasiocarpa* compared with factors such as site slope (Day and Duffy 1963), substrate or litter type (Day, 1964; Knapp and Smith, 1982). It was observed that viable seed production is not the only factor responsible for the successful establishment of *A. pindrow* seedlings. It is also related to predation and factors such as thick litter and humus layers which affect the moisture and root penetration of the germinated seedlings.

The high mortality of 1-3 year old seedlings may be due to poor root development during the initial establishment period, especially in the late spring when surface soil moisture is limited after snow melt. Singh and Singh (1984) reported that mortality rates of up to 81 percent among one year old seedlings were caused by drought, damping off fungi and Cockchafers. Sharma *et al.* (1986) reported that 85 to 92 percent survival rates were obtained from planting nursery raised *A. pindrow* seedlings in July and August, suggesting that August plantings should be preferred. Planting at this time is important because of the monsoons, when soil moisture is non limiting and root establishment is rapid. Knapp and Smith (1982) reported that *A. lasiocarpa* seedling mortality is greatest on sites with high solar radiation during spring when soil moisture is limiting.

The good survival rates of five to seven year old seedlings, in *Open* and shade conditions, provides evidence that age plays an important role in the survival of the seedlings. Singh and Singh (1981) suggested that *A. pindrow* seedlings, after one and a-half years in germination beds, should be grown three years in transplant beds to get stock of a sturdy enough size for planting. Singh and Sharma (1985) also reported that 4 to 5 year old nursery-raised seedlings generally gain a tap root length of 12.7 ± 3.4 cm which seems to be the most suitable size for out planting. This also supports the hypothesis that root development plays an important role in the initial establishment of the seedlings in the thick layers of litter and humus and in resisting the later competition from the surrounding vegetation. Knapp and Smith (1982) reported that the good root penetration of *A. lasiocarpa* seedlings accounts for the good survival of this species. Similar conclusions have been made by Noble and Alexander (1977) for spruce and fir species; by Ustin *et.al.* (1984) for *A. magnifica*; and by Ghent (1958) for *A. balsamea*.

CONCLUSIONS

The highest PAR level in the *Open* and under different cover conditions in the forest occurred in June, indicative of cloudless summer periods, and was lowest in September, reflecting the start of autumn. The PAR levels at seedling height were strongly affected by the type of vegetation cover. These effects were more pronounced under the shade of *Viburnum* and *Tree plus Viburnum*. Air temperature and humidity were not much different for the different cover conditions. Though natural regeneration was extremely poor, seedling survival is enhanced by shade in the first year of establishment. Seedlings beyond four years of age showed the highest survival rates.

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