EFFECT OF LIGHT AND WEED COMPETITION ON THE SURVIVAL AND GROWTH OF *ABIES PINDROW* SEEDLINGS OF VARIOUS AGES IN DIFFERENT SOIL MEDIA IN THE MOIST TEMPERATE FORESTS OF PAKISTAN

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ABSTRACT

Planting stock of silver fir raised in polythene tubes in common nursery soil and forest soil were kept (in poly bags) and planted bare-rooted at age 3, 12 and 24 months, under four cover conditions in the experimental site at Kund. The survival and growth of the seedlings were monitored over time. Both 3-month-old and 12-month-old plants in polythene tubes gave best survival rate under shade in all three cover condition. Under similar condition the survival rate was comparatively low for the seedling planted directly in forest soil due to root competition. For older plants (24-month-old) both shade and root competition are less important. Height growth of young seedling (3-24 month old) is not significantly affected by shade which is however highly co-related to seedling age. Significant growth was observed even under reduced PAR (2-4% of the open) showing the extreme shade-tolerant nature of the species. Age of the planting stocks therefore, plays an important role in the initial survival, establishment and growth of the seedling in natural forests.

INTRODUCTION

The fir forests constitute 45 percent of the coniferous forest area of Pakistan,and are important in meeting the timber demands of the country and catering to the needs of the local population for grazing their livestock. Empirical experiments have generally failed to enhance the regeneration of forest stands. Most researchers have suggested artificial planting of these forests to obtain a sustained yield in the future, and in most cases in India and Pakistan this is being done (Haq, 1992).

A dense forest canopy drastically modifies the quantity and quality (e.g. red/far red ratio) of the solar energy reaching the forest floor (Crawford, 1989; Kwesiga and Grace, 1986). Traditionally, most investigations on the effects of shading on plant growth and development have assumed that shading is synonymous with a decreased photon flux density (Coombe, 1957; Evans, 1969). Light on the floor of tropical rain forests is characterized by very low PAR levels, and low red/far red ratios (Bjorkman and Ludlow, 1972; Chazdon and Fletcher 1984; Whitmore, 1975). Low red/far red ratios influence the development of photosynthetic capacity and the process of natural regeneration. The effect of light quantity and quality act together in nature (Crawford, 1989).

Since the natural regeneration at Kund experimental site was very dispersed and patchy, and mortality rates were high, it was decided to investigate the performance of nursery-raised stock. It was observed during studies (Haq, 1992) that the mortality of seedlings up to 3 years of age is high, therefore, 3, 12 and 24 month old seedlings under four cover conditions, were selected for the study. Three soil treatments were also applied in order to investigate the survival and growth of seedlings planted in forest soil, nursery loam in tubes and forest soils in tubes. The experiment was laid out at Kund during May 1989.

MATERIALS AND METHODS

Study Area (Kund)

Experiments were carried out in almost pure stands of *Abies pindrow* at Kund. The experimental area is below a ridge about 2475 m in elevation 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 = ± 26.5 cm) and a mean height 36 m (SD = ± 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.

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 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 hours.

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.

Rainfall

Rainfall was collected in tins of 15 cm diameter that were placed at 25 cm above ground level, distributed randomly in the four replicated cover conditions and measured daily.

Experimental Layout

Three groups of 216 seedlings either 3, 12 or 24 months old were planted in the fenced area in a factorial design with three replicates. The four site conditions were taken as the main plot treatments namely, (a) *Open* (b) *Tree cover* (c) *Viburnum cover* (d) *Trees plus Viburnum.*

The treatments were the four cover types, 3 age groups and 3 planting systems. The three planting systems were (i) directly in forest soil (ii) nursery soil in polythene tubes size 7.5 x 18 cm (iii) forest soil in polythene tubes of size 7.5 x 18 cm. The tubes were used to eliminate competition from the surrounding vegetation for soil moisture. The nursery soil was generally a mixture of river sand and forest humus (3:1) and assumed to be more fertile. The forest soil was put in the same

size of plastic tubes and this treatment was introduced to highlight the effect of eliminating competition for soil moisture from the surrounding vegetation. The three sites were randomly selected in the fenced part of the experimental area and seedlings with different treatments were randomly allocated within each site (Fig 1). The experimental layout is shown in Table 1.

Table 1: Cover condition, soil and seedling age treatments at Kund

Cover conditions	Soil conditions		
	Direct (Forest soil)	Nursery soil (Tubes)	Forest soil (Tubes)
Open	3 months	3 months	3 months
	12 months	12 months	12 months
	24 months	24 months	24 months
Tree cover	3 months	3 months	3 months
	12 months	12 months	12 months
	24 months	24 months	24 months
Viburnum cover	3 months	3 months	3 months
	12 months	12 months	12 months
	24 months	24 months	24 months
Tree plus Viburnum cover	3 months	3 months	3 months
	12 months	12 months	12 months
	24 months	24 months	24 months

Seedlings were planted in May 1989 and watered daily for a period of six weeks. Failures were replaced. After that they were watered once a week depending upon the weather conditions. Seedling height and number of needles were recorded once a month. Data reported below relate to the period from May 1989 to October 1990. The data were analyzed by analysis of variance.

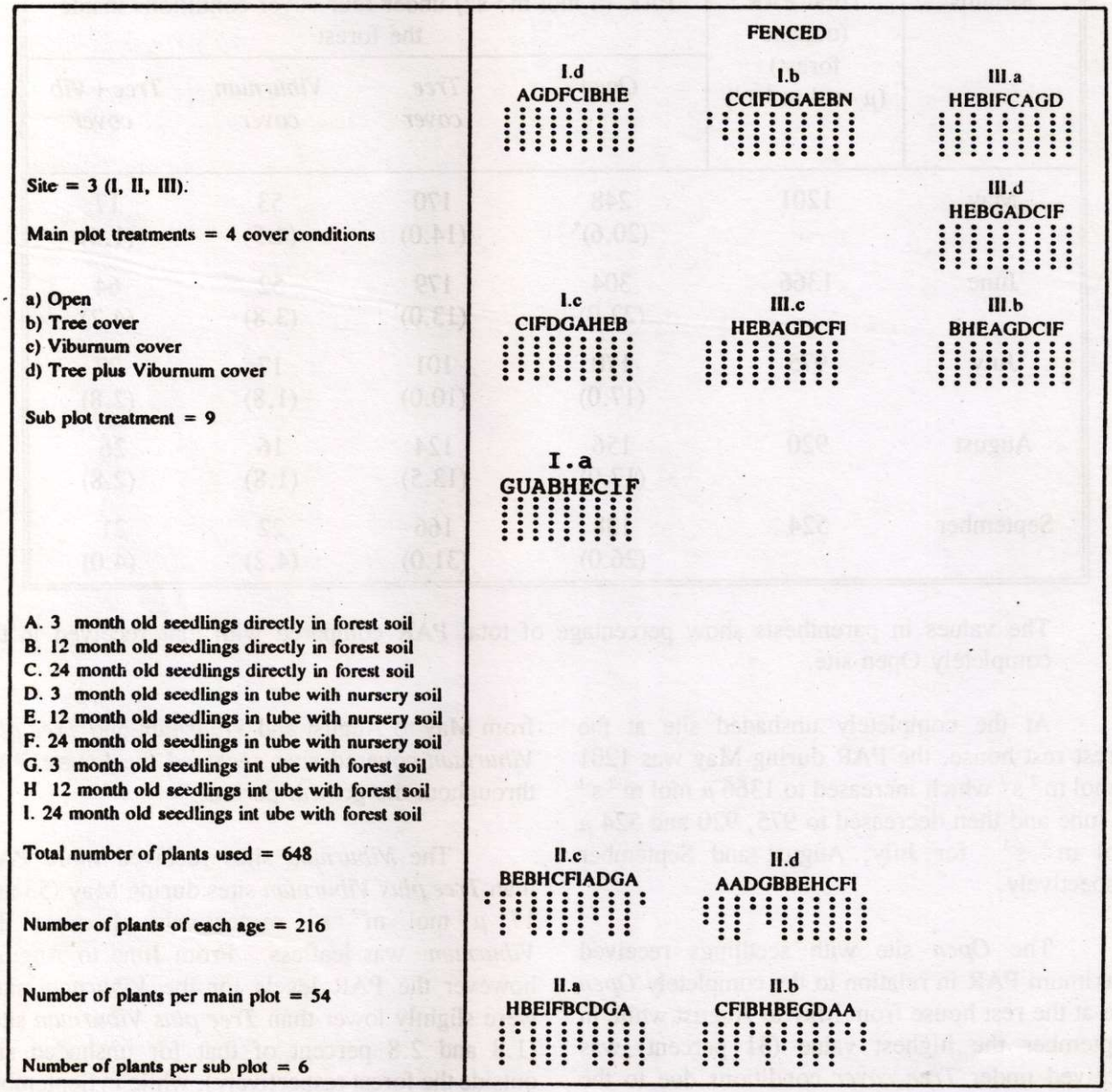
RESULTS

PAR values

The PAR data from May to September for the year 1989 are shown in Table 2.

Figure - 1 Layout of planted seedling experiment with different soil and cover conditions at Kund

Date of establishment - May, 1989



Scale: 1 cm = 5.75 m

Table 2: 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)

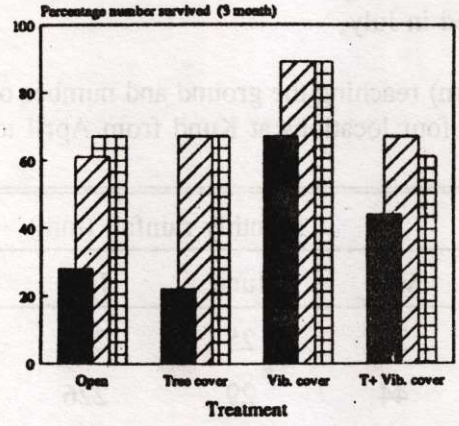
The values in parenthesis show percentage of total PAR compared with that received in the completely Open site.

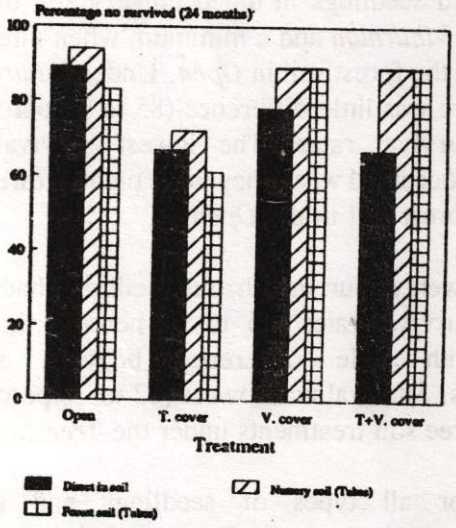
At the completely unshaded site at the forest rest house, the PAR during May was 1201 μ mol m^{-2} s^{-1} which increased to 1366 μ mol m^{-2} s^{-1} in June and then decreased to 975, 920 and 524 μ mol m^{-2} s^{-1} for July, August and September respectively.

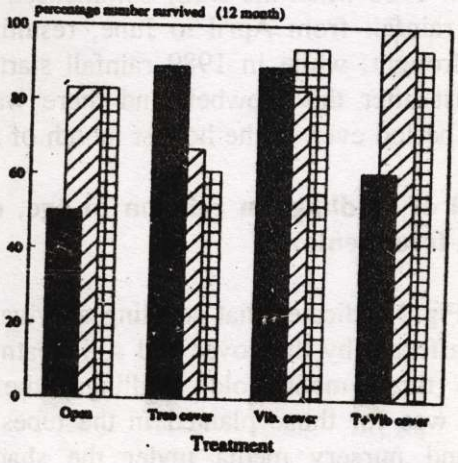
The *Open* site with seedlings received maximum PAR in relation to the completely *Open* site at the rest house from May to August while in September the highest value (31 percent) was received under *Tree cover* conditions due to the effect of the west facing aspect and the lower solar elevation interacting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

The *Viburnum* sites received more PAR than *Tree plus Viburnum* sites during May (53 and 17 μ mol m^{-2} s^{-1} respectively) because the *Viburnum* was leafless. From June to August, however the PAR levels for the *Viburnum* sites were slightly lower than *Tree plus Viburnum* sites (1.8 and 2.8 percent of that for unshaded site outside the forest respectively), while in September they were almost equal.

Fig 2 **Seedling survival after 18 months under different covers and soils**







Rainfall

The average rainfall in 1989 (Table 3) in the open for April, May and June was 34, 39 and 25 mm respectively. The maximum average monthly rainfall of 297 mm was received in July, August being the next with 136 mm. During September only 27 mm of rain was received in the *Open* sites. Precipitation under the trees and other vegetation types was also at a maximum in July.

Table 3: Average precipitation(mm) reaching the ground and number of rainy days each month (bold) from four locations at Kund from April to September 1989.

Cover type	Monthly rainfall (mm)					
	April	May	June	July	August	Sept
Open	39	39	25	297	136	27
Tree cover	18	44	29	226	88	9
Viburnum cover	29	48	20	271	124	16
Tree+Vib cover	18	39	25	297	136	27
No. of rainy days	**3**	**3**	**4**	**10**	**10**	**2**

Over the course of this study the annual rainfall differed considerably from April to June. In fact in 1988 when the study commenced there was no rainfall from April to June, resulting in severe drought, while in 1989 rainfall started in April just after the snowbelt and there was no drought period even in the hottest month of June.

Survival of seedlings in relation to age, cover and soil treatments

Fig.2 indicates that seedling survival was greatly affected by the cover and soil treatments. For the three month old seedlings, the best survival was for those planted in the tubes with forest and nursery media under the shade of *Viburnum cover*, while the minimum survival (26 percent) was planted directly in forest soil under the *Tree cover*.

100 percent survival occurred for 12 months old seedlings in tubed nursery soil under *Tree plus Viburnum* and a minimum when directly planted in the forest soil in *Open*. Under *Viburnum cover* there was little difference (85 to 95 percent) in the survival rates. The lowest survival of seedlings occurred when they were planted directly into the forest soil in the *Open*.

Twenty-four month old seedlings had the highest survival rates (85 to 93 percent) in the *Open* with little difference between soils treatments. Survival was lowest (62 to 70 percent) for the three soil treatments under the *Tree cover*.

For all types of seedlings and soils minimum survival occurred among 3 months old seedlings. The shade of *Viburnum* provided the best survival conditions for 3 and 12 months old seedlings.

Height and needle increase of seedlings in relation to cover and soil treatments.

The mean height increase of seedlings over two growth periods is shown in Fig 3. The height increase was different between groups of seedlings. The smallest height increase (1.1 cm) was obtained in three months old seedlings planted in forest soil under *Tree plus Viburnum cover* and greatest (2.36 cm) in the nursery soil (tubes) in the *Open*.

Twenty-four month old seedlings grew best (3.1 cm) under *Viburnum cover* in the forest soil (tubes) and worst (2.0 cm) when planted in nursery soil (tubes) under the same cover. While under the *Tree cover*, the greatest height increase (3.0 cm) was for seedlings growing directly in forest soil followed by seedlings in nursery soil (2.9 cm). In general for this age group, height growth was little affected by cover and soil.

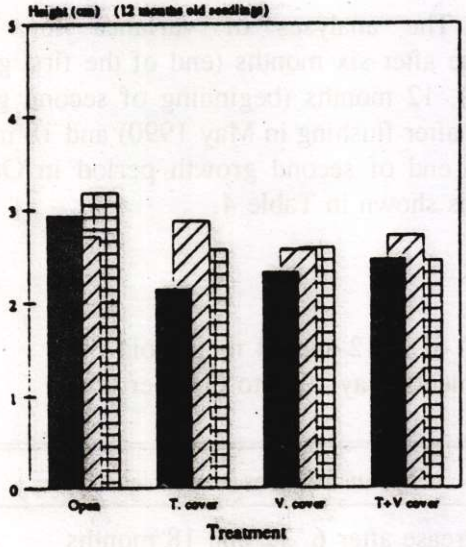
The analyses of variance for height increase after six months (end of the first growth period), 12 months (beginning of second growth period after flushing in May 1990) and 18 months (at the end of second growth period in October 1990) is shown in Table 4.

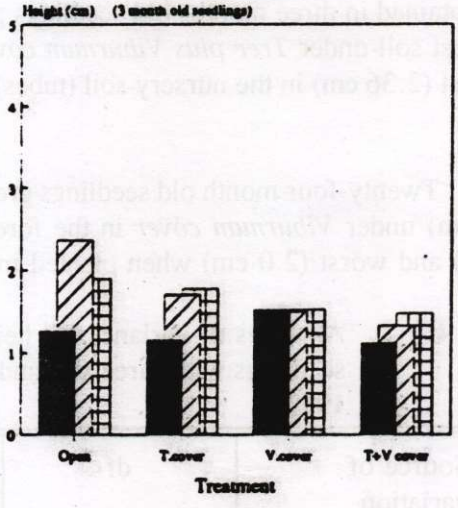
Table 4: Analyses of variance for height increase (cm) of 3, 12 and 24 month old seedlings with three soil and four cover treatments May 1989 to October, 1990

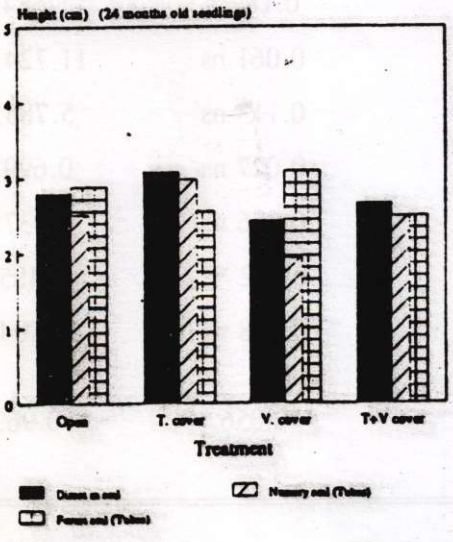
Source of variation	df	Mean Squares		
		Height increase after 6, 12 and 18 months		
		6	12	18
Rep	2	0.098 ns	4.134 *	5.184 ***
Cover	3	0.182 *	1.684 ns	2.053 ***
Age	2	0.061 ns	11.724 ***	1.627 **
Soil	2	0.113 ns	5.785 **	0.715
Cover x Age	6	0.027 ns	0.699 ns	0.518 ns
Cover x Soil	6	0.076 ns	1.037 ns	0.142 ns
Age x Soil	4	0.242 **	2.485 *	1.425 ***
Cover x Age x Soil	12	0.018 ns	1.704 *	0.631 *
Residual	610	0.056	0.969	0.294
Total	647			

*** = significant at $p < 0.001$ ** = significant at $p < 0.01$,* significant at 0.05, ns = not significant

Fig 3 Effect of cover and soil on height growth after 18 months of plantings







Cover significantly affected the height of seedlings after two growth periods (18 months). Height growth was also affected by the age of the seedlings. The significant effects of soil were also apparent 12 and 18 months after of planting. The interaction of soil and age accounted for same variation.

Needle numbers increase of seedlings in relation to cover and soil treatments

The mean needle increase for 3, 12 and 24 months old seedlings is shown in Fig. 4. The needle increase in 3 month old seedlings was not significantly affected by the cover or soil. In 12 month old seedlings it was affected by both cover and soil treatments with a maximum increase (37 needles) in nursery soil (tubes) under *Tree cover*. The needle increase under *Viburnum cover* was lowest among all the treatments.

The needle increase of 24 months old seedlings was greatly affected by the cover and soil treatment. The greatest increase occurred in seedlings grown in nursery and forest soil (tubes) (49 and 47 respectively) was under *Tree cover seedlings* (45 numbers followed by *Open* (41 numbers) in forest soil (tubes) and the lowest increase (4 numbers) occurred in directly planted under *Tree plus Viburnum.*

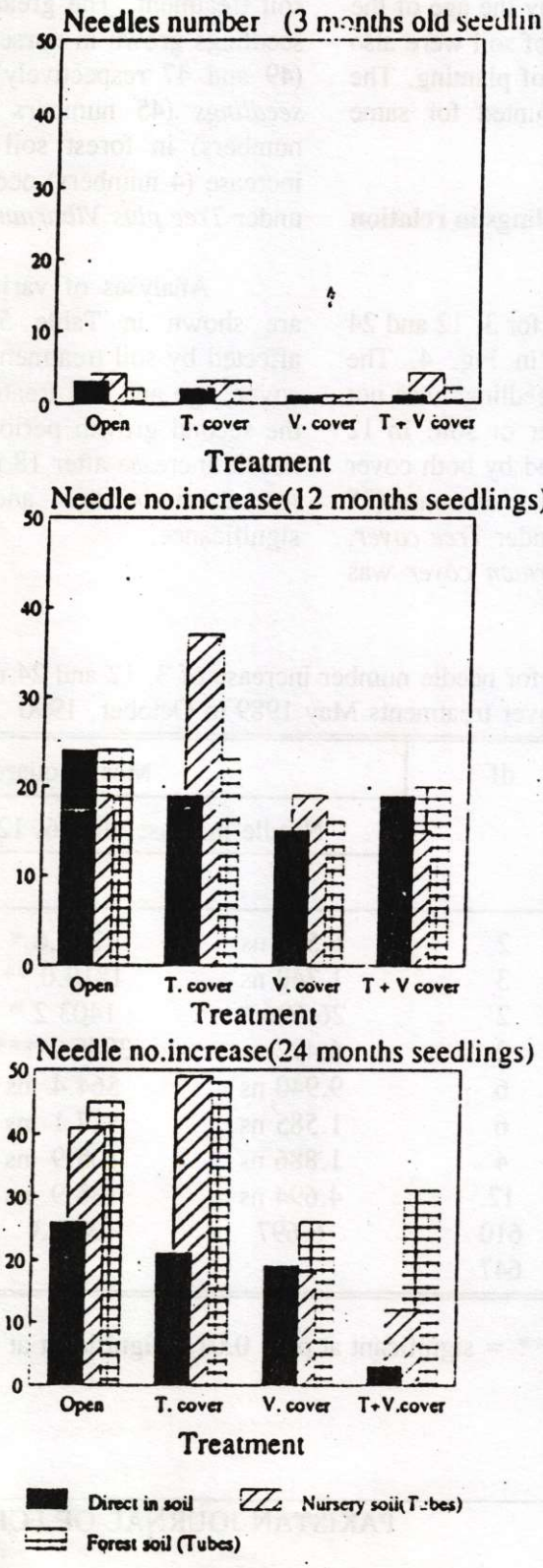
Analyses of variance for needle increase are shown in Table 5. Needle increase was affected by soil treatment after 12 months and by cover, age and soil treatments after 12 months in the second growth period. Soil had no effect on needle increase after 18 months when interactions for cover x age and age x soil showed significance.

Table 5: Analyses of variance for needle number increase of 3, 12 and 24 months old seedlings with three soil and four cover treatments May 1989 to October, 1990

Source of variation	df	Mean Squares		
		Needle increase after 6, 12 and 18 months		
		6	12	18
Rep	2	5.576 ns	1339.6 *	861.1 ***
Cover	3	1.340 ns	1810.0 **	599.6 **
Age	2	26.696 *	1403.2 *	528.3 **
Soil	2	6.492 ns	3945.2 ***	138.2 ns
Cover x Age	6	9.940 ns	564.4 ns	279.1 **
Cover x Soil	6	1.585 ns	417.1 ns	25.62 ns
Age x Soil	4	1.886 ns	805.9 ns	400.5 *
Cover x Age x Soil	12	4.694 ns	138.9 ns	132.5 ns
Residual	610	6.697	378.3	113.7
Total	647			

*** = significant at $p < 0.001$ ** = significant at $p < 0.01$,* significant at 0.05, ns = not significant

Fig. 4 Effect of cover and soil on needle increase 18 months after planging



DISCUSSION

The effect of shading and soil on the survival and growth of *Abies pindrow* seedlings of three different ages with and without competition from other roots was investigated by raising the seedlings in the plastic tubes at Kund. Besides direct competition the composition of the established vegetation surrounding the seedlings may also affect the likelihood of their being damaged by grazing animals to which they are particularly vulnerable (Salihi and Norton, 1987; Oesterheld and Sala, 1990). Hazards from domestic livestock were eliminated by replicating the experiment in the fenced part of the area.

Seedling survival in relation to cover and soil conditions.

The early growth of a seedling is perhaps the most vulnerable stage in the life cycle of a plant (Fenner, 1985). The fact that maximum survival of three month old seedlings under *Viburnum cover* shows their shade tolerant nature. This also indicates that the presence of shade is an advantage for the initial establishment and survival of seedlings. This effect was more pronounced in the seedlings grown in forest and nursery soils (tubes) indicating that elimination of root competition also improves survival. The low survival of three month old seedlings under *Open* and *Tree cover* indicates the considerable stress that high radiation levels reaching the forest floor imposes on seedlings (Fig. 3). The effect of high radiation on the survival of 3 month old seedlings in via higher heat loading temperature resulting in desiccation. The fact that seedling grown in tubes with nursery soil and forest soils had the highest survival rates under shade and *Open* also indicates the importance of moisture. This was due to the diminished competition for soil moisture from surrounding vegetation. Shading has been shown to increase seedling mortality of some species due to mechanical instability of the etiolated shoots (Grime and Jeffrey, 1965) or due to the increased susceptibility to fungal attack (Grime,1986).

The shade of trees and shrubs also improved the survival of 12 month old seedlings. In this case higher survival rates were shown by the seedlings grown directly in forest soil under the shade of *Tree cover* and *Viburnum* indicating that the effect of competing roots was less on 12 month old seedlings compared to 3 month old ones. The low survival rates of seedlings planted directly in the forest soil in the *Open* clearly shows the combined effect of high radiant energy on the forest floor and competition from the roots of surrounding ground vegetation. Conard and Radosevich (1982) reported that several factors contribute both to growth inhibition and mortality of white fir seedlings. These include yellowing of foliage and premature needle cast. Winter desiccation also contributes to foliar damage and in extreme cases mortality of the seedlings. Sudden exposure of shade needles to high radiation and a high evaporative demand may also affect needle cast. Shading provides partial protection from winter desiccation and high radiation and improve the survival and growth of the seedlings. The 24 months old seedlings survived almost completely in the *Open*.

The good survival rates of one year old and older seedlings when planted directly in forest soil indicates that light and competition from the roots of the surrounding vegetation have little affect on these seedlings. The finding of Singh and Sharma (1985) and Sharma *et al.* (1986) demonstrated that the age and size of planting stock is important for the initial survival and establishment of fir seedlings. These findings are also supported by Knapp and Smith (1982) who have shown that good root development and penetration of *A. lasiocarpa* seedlings accounts for the high survival rate of this species. Similar

conclusions have been by Ustin *et al.* (1984) for *A. magnifica*.

Height growth of seedlings in relation to cover and soil conditions

Although dry weight is a useful measure of plant growth, in a competitive environment, height growth may be more important (Helliwell *et al.* 1991). The height growth rates of *Abies pindrow* is slow. The height increase over 18 months for 3 month old seedlings was not more than 1.5 cm, and for 24 month old seedlings 3.1 cm. Singh and Sharma (1985) observed growth of less than 16 cm in nursery raised four-and-half year old *Abies pindrow* seedlings. Growth is generally very slow in other *Abies* species. Conard (1980) reported that although seedlings were abundant under shrub cover, growth was slow, with the result that trees of 25 to 30 years old were often less than 1 m tall and still beneath the shrub canopy. Seventy-five to 100 years may be required for white fir to emerge above canopy and shade out shrubs. Conard (1980) also reported that dramatic height increases of white fir seedlings under shade indicate the shade-tolerant nature of the species which is apparently able to photosyntheses well at very low light intensities.

Competition has been defined as a tendency of two plants to try to use the same quantum of light, ion of mineral nutrient, molecule of water, or volume of space (Grime, 1973). Studies on light, moisture, and nutrient limitations on growth indicate that light is often a dominant factor influencing seedling vigour and growth (Reed *et al.* 1983 and Eissentant and Mitchell, 1983). Savill and Evans (1986) stated that weeds compete with young trees for light, water, and nutrients and hence retard growth. Availability of soil nutrients may improve seedling growth even under canopies (Peace and Grubb, 1982) or in competition with established plants (Snaydon and Howe, 1986). Flint and Childs (1987) reported that competing vegetation seemed to a most instrumental in influencing water availability to Douglas-fir seedlings and thus affects seedling growth. Fairbairn and Neuštein (1970) reported maximum height growth in pine seedlings in shade in the absence of weeds. That the height growth of *Abies pindrow* seedlings was generally higher even when planted in the tubes indicates that elimination of competition improves seedling height growth in younger stages and these effects were most pronounced at the youngest age of 3 months when planted in the *Open*. However, competition for nutrients does not seem to be of major importance in the first few years. Eissentant and Mitchell (1983) reported similar observations for Douglas-fir seedlings.

CONCLUSIONS

The survival of 3 and 12 month old seedlings is significantly improved by planting in tubes. The low survival rate of 3 and 12 month old seedlings planted directly in forest soil, probably indicates the effects of competition for soil moisture on their initial establishment. The high survival of 24 month old seedlings planted directly in forest soil in the *Open* however, suggests that for old seedlings *shade*, and computational effects, are less important. The age of the planting stock therefore plays an important role in the initial survival and establishment of the seedlings in natural forests. Height growth of young seedlings (3-24 months old) is very slow and is significantly related to their age.

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BIBLIOGRAPHY

Bjorkman, O. and Ludlo, M. M. (1972). Characterization of light climate on the forest floor of a Queensland rain forest. *Carnegie Institute Yearbook 71*: 85-94.

Chazdon, R. L. and Fletcher, N. (1984). Light environment of tropical trees. In *Physiological Ecology of Plants in the Wet Tropics*, [eds]. Medina, E., Moony, H.A., and Vazquez-yans, C. pp. 27-36. Junk Netherlands.

Conard, S. G. (1980). Species interactions, succession, and environment in the montane chaparral white fir vegetation of the northern Sierra Nevada, California. Ph. D. Diss, Univ Calif, Davis.

Conard, S. G and Radosevich, S. R. (1982). Growth responses of white fir to decreased shading and root competition by montane chaparral shrub. *For. Sci*, 28:309-320.

Crawford, R. M. M. (1989). Studies in plant survival. Ecological case histories of plant adaptation to adversity. Blackwell Scientific Publications, Oxford: 159-202.

Eissentant, D. M. and Mitchell, J. E. (1983). Effects of seeding grass and clover on growth and water potential of Douglas-fir seedlings. *For. Sci. 29*: 166-179.

Evans, G. C. (1969). The spectral composition of light in the field. 1. Its measurement and ecological importance. *Journal of Ecology 56*: 109-125.

Fairbairn, W. A. and Neustein, S. A. (1970). Study of response of certain coniferous species to light intensity . *Forestry*. XLIII : 57-71.

Fenner, M. (1985). *Seed Ecology*. Chapman and Hall, London.

Flint, L. E. and Childs, S. W. (1987). Effect of shading, mulching and vegetation control on Douglas-fir seedling growth and soil water supply. *Forest Ecology and Management 18*:189-203.

Grime, J. P. (1973). Competition and diversity in herbaceous vegetation- a reply. *Nature 244*: 310-311.

Grime, J. P. (1986). Shade tolerance in flowering plants. *Nature 208*: 161-163.

Grime, J. P. and Jeffrey, D. W. (1965). Seedling establishment in vertical gradients of sunlight. *Journal of Ecology, 53*: 621-642.

Haq, R.U. (1992). Ecophysiology of natural regeneration of *Abies pindrow* in the moist temperate forests of Pakistan. Department of Plant Sciences, University of Oxford. PP: 152. Unpublished D.Phil thesis.

Knapp, A. K. and Smith, W. K. (1982). Factors influencing understorey seedling establishment of Engelmann, spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) in Southeast Wyoming. *Can. J. Bot: 60*: 2753-2761.

Kwesiga, F. R. and Grace, J. (1986). The role of the red/far red ratio in response to tropical tree seedlings to shade. *Annals of Botany 57*: 283-290.

Oesterheld, M. and Sala, O. E. (1990). Effects of grazing on seedling establishment: the role of seed and safe-site availability. *J. veget. sci. 1*: 353-358.

Peace, W. J. H. and Grubb. P. J.(1982). Interaction of light and mineral nutrient supply in the growth of *Impatiens parviflora*. *New Phytologist 90*. 127-150.

Reed, K.C.; Shumay, J. S.; Walker, R. B and Bledsoe, C. S. (1983). Evaluation of the interaction of two environmental factors affecting Douglas-fir seedling growth: light and nitrogen. *For. Sci. 29*: 193-203.

Salihi, D. O. and Norton, B. E. (1987). Survival of grass seedlings under intensive grazing in semi-arid rangelands. *Journal of Applied Ecology 24*: 145-151.

Sharma, H. P.; Sharma, K. C. and Ombir, Singh. (1986). Nursery technology of spruce (*Picea smithiana*). *Indian Forester 112*: 13-17.

Singh R.V. and Sharma K.C. (1985). Effect of root pruning on the growth of Transplanted Silver fir seedlings. Indian Forester 111: 58-61.

Snaydon, W. and Howe, C. D. (1986). Root and shoot competition between established ryegrass and invading grass seedlings. *Journal of Applied Ecology 23*: 667-674.

Ustin, S. L.; Woodward, R. A. and Barbour, M. G. (1984). Relationship between sunfleck dynamics and red fir seedling distribution. *Ecology 65*: 1420-1448.

Whitmore, T. C. (1975). Tropical rain forests of the Far East. Clarendon Press, Oxford.