STRUCTURAL ATTRIBUTES AND GROWING STOCK VARIATIONS ON DIFFERENT ASPECTS OF HIGH HIMALAYAN AND SIWALIK CHIR PINE FORESTS

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SHARMA, C. M. & BADUNI, N. P. 2000. **Structural attributes and growing stock variations on different aspects of high Himalayan and Siwalik chir pine forests.** In a comparative analysis of high Himalayan and Siwalik chir pine forests, *Pinus roxburghii* (chir pine) recorded in the former, higher values of density (980 trees ha^{-1} on SW aspect), total basal cover (60.30 m^2 ha^{-1} on NE aspect), importance value index (300 on SW aspect) and concentration of dominance (0.8447 on NE aspect), while in the latter, higher values of diversity (maximum 0.5248 on SW aspect) in the tree layer. The maximum total growing stock value (440 m^3 ha^{-1} on the NE aspect) was observed in the high Himalayan chir pine forest, whereas the minimum value (67.76 m^3 ha^{-1} on SW aspect) was observed in the Siwalik chir pine forest. Generally the soils of the high Himalayan chir pine forests are more suitable for *Pinus roxburghii.*

Key words: Garhwal Himalaya - quantitative analysis - growing stock - soil analysis - diversity index - aspects

SHARMA, C. M. & BADUNI, N. P. 2000. **Kepelbagaian sifat struktur dan pertumbuhan stok terhadap aspek-aspek yang berbeza di hutan chir pine Himalaya tinggi dan hutan chir pine Siwalik.** Dalam analisis perbandingan bagi hutan chir pine Himalaya tinggi dan hutan chir pine Siwalik, *Pinus roxburghii* (chir pine) dicatatkan dalam hutan chir pine Himalaya tinggi dengan nilai kepadatan yang lebih tinggi (980 pokok ha^{-1} untuk aspek SW), jumlah litupan pangkal (60.30 m^2 ha^{-1} untuk aspek NE), indeks nilai kepentingan (300 untuk aspek SW) dan tumpuan dominans (0.8447 untuk aspek NE), manakala hutan chir pine Siwalik mencatatkan nilai kepelbagaian yang lebih tinggi (maksimum 0.5248 untuk aspek SW) dalam lapisan pokok. Jumlah nilai pertumbuhan stok minimum (440 m^3 ha^{-1} untuk aspek NE) dicerap di hutan chir pine Himalaya tinggi, manakala nilai minimum (67.76 m^3 ha^{-1} untuk aspek SW) dicatatkan di hutan chir pine Siwalik. Pada umumnya tanah di hutan chir pine Himalaya tinggi lebih sesuai untuk *Pinus roxburghii.*

Introduction

Pinus roxburghii Sarg. (commonly known as chir pine or Himalayan long needle pine) is native to Himalaya, occurring between 450 and 2300 m above sea-level in nearly all principal valleys, where the full force of the monsoon is felt. In Himalaya it covers wide areas as pure forests and also in mixtures with other broad-leaved and coniferous species such as *Quercus leucotrichophora, Rhododendron arborium, Lyonia ovalifolia, Myrica esculenta, Cedrus deodara* and *Pinus wallichiana* towards its upper limit and *Shorea robusta, Anogeissus latifolia, Ougeinia oojeinensis* and *Bauhinia variegata* towards the lower limit. It is a fire resistant indigenous tree species which at higher elevations prefers hotter slopes and drier areas. In the Siwalik area it is found in groups in the form of strips in association with broad-leaved species. Certain qualities such as high regeneration potential (Kumar & Bhatt 1990), capacity to colonise degraded habitats (Joshi 1990), rapid growth (Misra & Lal 1984), straight cylindrical bole and high volume returns (Singh 1979) and ability to yield considerable amount of resin (Deshmukh 1966) make this species a precious resource in this region.

Although preliminary information on species composition, diversity and regeneration behaviour of certain Indian central Himalayan conifer forests has been recorded by various workers (Saxena & Singh 1982, Singh & Singh 1987, Sundriyal & Bisht 1988, Agrawal *et al.* 1993, Baduni & Sharma 1997), detailed quantitative information on the population structure of chir pine forests at different sites of the Garhwal Himalayan region is still lacking. Information on the percentage growing stock distribution under different diameter classes in even-aged and uneven-aged forests is also an essential prerequisite for sound forest management practices (Paivinen 1980, Little 1983, Hokka *et al.* 1991, Maltamo *et al.* 1995).

Therefore, the present study was aimed to compare the structural attributes, regeneration behaviour and growing stock variations on various aspects of two different elevational pine forests to demonstrate how the density and demography of *P. roxburghii* change as a function of exposure and elevation. The findings of the study will be helpful in predicting the population structure for future harvest and making management recommendations to characterise habitat preferences of this species for use in planning production.

Materials and methods

Study area and climate

The Pauri Garhwal (29° 20' – 30° 15' N, 78° 10' – 79° 20' E), a hill district, is situated in central-western Himalaya. Most of the district is between 900 and 1800 m above sea-level (asl) and is fully or partially covered with chir pine forests. The Siwalik chir pine forests occur in the form of strips below 1250 m asl in the Dabrad, Deogaddi and Fatehpur (Dugadda) areas of the upper Siwalik region, whereas the high Himalayan chir pine forests are found distributed above 1250 m asl on nearly the whole district (Figure 1.). Wildfire is a regular phenomenon in these forests and can have a profound effect on their structure and composition (depending on its intensity). The average annual rainfall in the high Himalayan chir pine forests ranges from 1120 to 1570 mm, whereas in the Siwalik chir pine forests the average annual rainfall ranges from 1500 to 1757 mm. In the high Himalayan chir pine forests the minimum temperature is as low as 5 °C in December and the maximum temperature goes up to 32 °C in May. Similarly in the Siwalik chir pine forests the mean minimum temperature has been recorded as 13 °C in December and mean maximum temperature as 37 °C in May. Snowfall occurs only in the upper reaches of the high Himalayan chir pine forests but rarely stays for more than 3–5 days.

Vegetational sampling and analysis

The quantitative assessment of the vegetation was accomplished by 10×10 m randomly laid quadrats. A total of 80 quadrats (10 on each site/aspect and 40 for each forest) were selected at random and studied. The size and number of quadrats

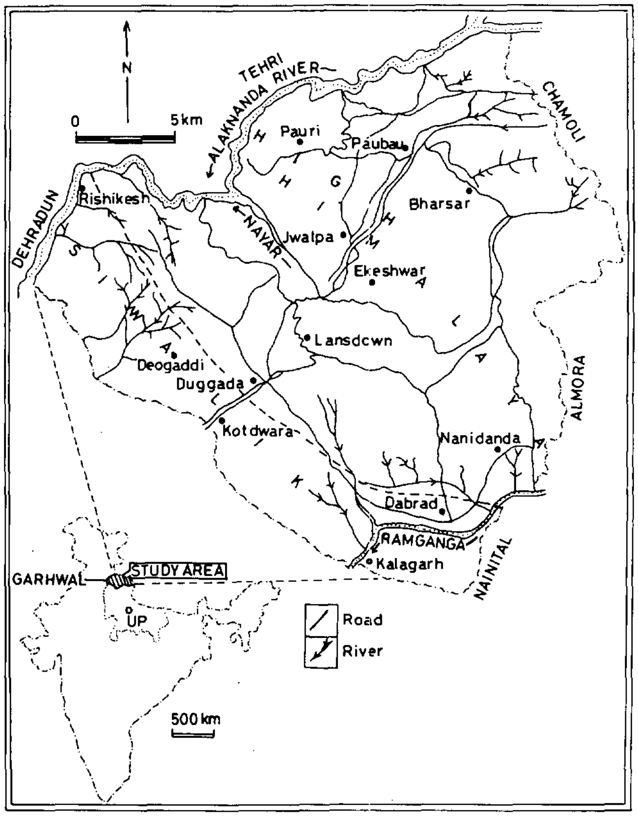


Figure 1. Location map of the study area

needed for vegetation sampling and analysis were determined by the species – area curve (Misra 1968) and the running mean method (Kershaw 1973). The circumference at breast height (cbh 1.37 m above the ground) of each tree in each quadrat was measured. Individuals of trees with 10–31.5 cm cbh were recorded as saplings (Knight 1963). The vegetational data were quantitatively analysed for abundance, density and frequency (Curtis & McIntosh 1950). The importance value index (IVI) was determined as the sum of the relative frequency, density and dominance (Curtis 1959). The diversity ($\bar{H}$) was computed using Shannon-Wiener information index (1963) as $\bar{H}$ = (Ni/N) $\log_2$ (Ni/N), where *Ni* is the total density values for species *i*, and *N* is the total density value of all species in that stand. The expression of diversity was calculated in the unit of bits per individual. The concentration of dominance (*cd*) was determined by Simpson's (1949) index, as $cd = (Ni/N)^2$, where *Ni* and *N* were same as for Shannon-Wiener information index. The growing stock estimation of *P. roxburghii* was done on the basis of standard volume equation, mentioned in the Indian Forest Records (FRI publication) as $V = 0.00249 + 0.27408\ D^2\ H$ (FSI 1985), where V = volume, D = diameter and H (in this case) = height.

The soil samples from different sites/aspects were collected from the top (0–10 cm), middle (11–20 cm) and lower (21–30 cm) layers of the profile and the values were averaged to compare the physico-chemical properties on each aspect of both forests. The colour of the soil was directly seen from the Munsell soil colour chart.

The texture of the soils was assessed following USDA (1975). The moisture percentage and water holding capacity of the soils were recorded following Misra (1968). The pH of the soils was measured with the help of saturated paste technique using EC and pH meters (Rhodes 1982). The organic carbon percentage was measured by the potassium dichromate reduction method and by subsequent spectrophotometric measurements (Nelson & Sommers 1982). The extractable phosphate was measured using sodium bicarbonate extracts (Olsen *et al.* 1954). The total nitrogen was assessed by the standard Kjeldahl's procedure (Bremner & Mulvaney 1982).

Results and discussion

In Himalaya the northeast facing aspects are considered cooler and moister due to the availability of shorter insolation periods in a day, as compared to the southwest facing aspects, which receive longer insolation periods, and therefore, are treated as drier and hotter as a rule. In the high Himalayan chir pine forests, *P. roxburghii* is found mostly in monospecific conditions on warmer southwest facing aspects, whereas in the Siwalik Chir pine forests it is present in groups with scattered lower deciduous trees, more numerous on depressions and cooler eastern aspects.

Vegetational analysis

In the high Himalayan chir pine forests (HHCPF), *P. roxburghii* was found associated with *Myrica esculenta* on the NE aspect, *Quercus leucotrichophora* on the NW aspect; and *Quercus leucotrichophora* and *Lyonia ovalifolia* on the SE aspect; however, it is monospecific on the SW aspect, in the tree layer. Similarly in the Siwalik chir pine forests (SWCPF), *P. roxburghii* was found associated with *Quercus leucotrichophora, Shorea robusta* and *Lyonia ovalifolia* on the NE aspect; *Quercus leucotrichophora, Shorea robusta* and *Rhododendron arborium* on the NW aspect; *Shorea robusta* and *Ougeinia oojeinensis* on the SE aspect; and with *Shorea robusta, Anogeissus latifolia* , *Terminalia alata* and *Mallotus philippinensis* on the SW aspect in the tree layer. But because of complete dominance of *P. roxburghii* on all aspects of both forests with respect to IVI and TBC (total basal cover) values, only the analysis of *P. roxburghii* individuals is being presented. The vegetational analysis of tree, sapling and seedling layers of *P. roxburghii* in the HHCPF and SWCPF was done to assess the habitat suitability of *P. roxburghii* on various aspects.

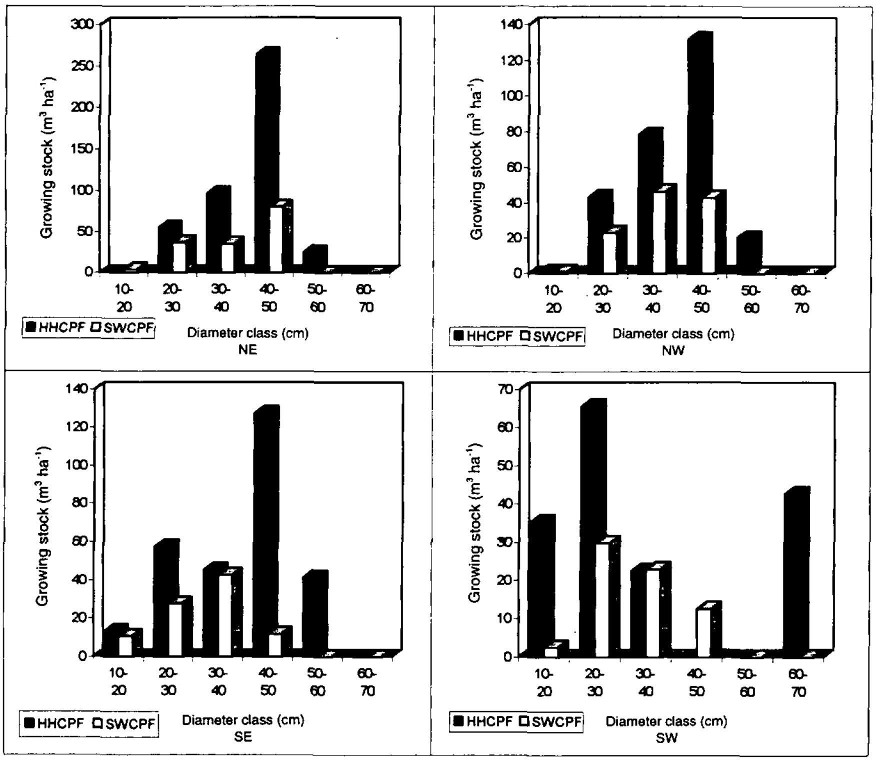
The tree density and IVI values in the HHCPF and SWCPF oscillated widely from one aspect to another. In the HHCPF the maximum tree density (980 trees ha^{-1}) and IVI (300) values were recorded on the warmer SW aspect, because on this aspect the *P. roxburghii* was monospecific in nature. In the SWCPF the maximum tree density (440 trees ha^{-1}) and IVI (188.86)values were observed on the SE aspect, because of higher dominance of *P. roxburghii* individuals. The minimum density of tree individuals (390 trees ha^{-1}) and IVI (237.93) values in the HHCPF were observed on the NW aspect, whereas the minimum density (170 trees ha^{-1}) and IVI (98.12) values in the SWCPF were observed on the warmer SW aspect, because on this aspect the dominance was also shared by other broad-leaved species. In both forests the lower density and IVI values could be attributed to lesser habitat suitability of *P. roxburghii* individuals (Table 1).

Table 1. Structural attributes and regeneration potential of *Pinus roxburghii* on different aspects of the high Himalayan and Siwalik chir pine forests

Aspect	Forest type	Frequency	Density (trees ha^{-1})	Total basal cover (TBC) (m^2 ha^{-1})	Importance value Index (IVI)	Concentration of dominance (*cd*)	Diversity (*H*)
	Tree						
	HHCPF	100	520	60.30	275.75	0.8447	0.0765
NE	SWCPF	100	280	17.95	177.83	0.3357	0.4683
	Sapling						
	HHCPF	-	-	-	-	-	-
	SWCPF	40	120	0.6325	300.00	-	-
	Seedling						
	HHCPF	-	-	-	-	-	-
	SWCPF	60	380	0.1398	300.00	-	-
	Tree						
	HHCPF	100	390	33.81	237.93	0.6290	0.2795
NW	SWCPF	100	240	16.22	174.79	0.3394	0.4694
	Sapling						
	HHCPF	80	480	2.10	300.00	-	-
	SWCPF	60	320	1.41	207.22	0.4770	0.1510
	Seedling						
	HHCPF	-	-	-	-	-	-
	SWCPF	40	280	0.117	300.00	-	-
	Tree						
	HHCPF	100	640	32.47	257.99	0.7383	0.1349
SE	SWCPF	100	440	13.17	188.86	0.3963	0.3616
	Sapling						
	HHCPF	-	-	-	-	-	-
	SWCPF	40	160	0.72	94.55	0.0992	0.5162
	Seedling						
	HHCPF	60	440	0.23	300.00	-	-
	SWCPF	60	120	0.05	219.33	0.5345	0.3112
	Tree						
	HHCPF	100	980	30.82	300.00	-	-
SW	SWCPF	80	170	11.27	98.12	0.1069	0.5248
	Sapling						
	HHCPF	80	680	2.82	300.00	-	-
	SWCPF	-	-	-	-	-	-
	Seedling						
	HHCPF	40	160	0.08	300.00	-	-
	SWCPF	20	40	0.02	98.87	0.5250	0.4999

* HHCPF = high Himalayan chir pine forest
* SWCPF = Siwalik chir pine forest
* NE = northeast aspect
* NW = northwest aspect
* SE = southeast aspect
* SW = southwest aspect

The TBC values in these forests varied from 11.27 m^2 ha^{-1} on the SW aspect of the SWCPF to 60.30 m^2 ha^{-1} on the NE aspect of HHCPF. The TBC of *P. roxburghii* was markedly greater (30.82–60.30 m^2 ha^{-1}) in the HHCPF as compared to SWCPF (11.27–17.95 m^2 ha^{-1}). Low TBC values in spite of high tree densities on the SW aspect of the HHCPF and the SE aspect of the SWCPF were the outcome of existence of immature forests on these aspects (Figure 2.). Higher TBC values in the HHCPF (60.30 m^2 ha^{-1}) and the SWCPF (17.95 m^2 ha^{-1}) were noticed on the NE aspect, because in the HHCPF, maximum chir pine individuals were found growing in higher diameter classes (Figure 2) and in the SWCPF the moisture conditions were congenial for the



NE = northeast aspect SE = southeast aspect
NW = northwest aspect SW = southwest aspect

Figure 2. Growing stock variations under various diameter classes of *Pinus roxburghii* on different aspects of the high Himalayan chir pine (HHCPF) and Siwalik chir pine (SWCPF) forests

growth of *P. roxburghii*. Lower TBC values in the HHCPF (30.82 m^2 ha^{-1}) and the SWCPF (11.27 m^2 ha^{-1}) were recorded on the SW aspect (Table 1), because in the HHCPF the chir pine forest was in regenerating phase and in the SWCPF the SW aspect did not form a suitable habitat for the growth of *P. roxburghii* individuals.

The highest numbers of saplings in the HHCPF (680 saps ha^{-1}) and SWCPF (320 saps ha^{-1}) were recorded on the SW and NW aspects respectively. No saplings were observed on the NE and SE aspects of the HHCPF and the SW aspect of the SWCPF (Table 1). The maximum numbers of seedlings in the HHCPF (440 seedls ha^{-1}) and SWCPF (380 seedls ha^{-1}) were observed on the SE and NE aspects respectively. No seedlings growth was recorded on the NE and NW aspects of the HHCPF, whereas minimum (40 seedls ha^{-1}) growth of the seedlings was recorded on the SW aspect of SWCPF (Table 1).

Several workers (Killingbeck & Wali 1978, Saxena & Singh 1982) have reported the ranges of TBC and density for similar types of forests from 15.61 to 59.30 m^2 ha^{-1} and from 350 to 2080 trees ha^{-1} respectively. Ralhan *et al.* (1982) has also reported the ranges of TBC and density from 26.86 to 60.45 m^2 ha^{-1} and 389 to 1633 trees ha^{-1} for temperate forests of Kumaun Himalaya. The values of TBC and density in the

HHCPF were, therefore, within the reported ranges; however, in the SWCPF these values were less than the reported ranges because of prevalence of comparatively imperfect habitat conditions for *P. roxburghii* in these forests.

On the SW aspect of the HHCPF the monospecific forest exhibited zero species diversity. The maximum species diversity (0.5248) in the tree layer of the SWCPF was recorded on the SW aspect (Table 1), which also indicated the sharing of community resources by other companion species. High species diversity is an indication of maturity in the ecosystem (Margalef 1963, Odum 1969). Low species diversity on the NE aspect of the HHCPF (0.0765) may be due to elimination of other species through competition. The values of diversity on different aspects of both the forests were observed less than the earlier reported values (0.8 to 3.4) for temperate forests (Monk 1967, Risser & Rice 1971, Saxena & Singh 1982, Ralhan *et al.* 1982). The concentration of dominance (*cd*) is generally inversely related to species diversity, that is why high *cd* value was recorded on NE aspect (0.8447) of the HHCPF and low *cd* value (0.1069) on the SW aspect of the SWCPF, where high diversity persisted (Table 1). The reported range of *cd* values by Whittaker (1965) for temperate forests (0.09 to 0.12) is far behind the values of the present study, because on all the aspects of both forests *P. roxburghii* has shown an absolute dominance in terms of TBC and IVI values.

Growing stock

In the high Himalayan chir pine forest, on the NE aspect the maximum number of individuals (190 trees ha^{-1}) was observed under the higher diameter class (40–50 cm) possessing a larger growing stock value (264.40 m^3 ha^{-1}) which has resulted in the highest total growing stock value (440.91 m^3 ha^{-1}) on this aspect (Figure 2). This was because of lesser species diversity and moreover, the *P. roxburghii* formed a mature established forest on the NE aspect. On the NW and SE aspects of the HHCPF, the maximum growing stock of the *P. roxburghii* was observed under 40–50 cm diameter class (131.83 m^3 ha^{-1} and 127.6 m^3 ha^{-1} respectively) but due to higher species diversities the growth of the chir pine individuals was not up to the mark (Figure 2). However, on the SW aspect of the HHCPF, although the *P. roxburghii* was monospecific, but due to the regenerating nature of the forest, the total growing stock value was not remarkable (165.62 m^3 ha^{-1}), because the highest number of individuals of this species (600 trees ha^{-1}) was recorded under a lower diameter class (10–20 cm); the number decreased subsequently under higher diameter classes until the diameter class of 60–70 cm where it rose to give the second largest number on this aspect (Figure 2).

In the Siwalik chir pine forest, the *P. roxburghii* was found distributed between 10–20 and 40–50 cm diameter classes on all the aspects. The growing stock under different diameter classes on the northern (cooler) aspects was higher than that of the southern (warmer) aspects (Figure 2). On the NE aspect, the *P. roxburghii* exhibited maximum growing stock (80.22 m^3 ha^{-1}) under 40–50 cm diameter class, thus the highest total growing stock value (156.27 m^3 ha^{-1}) was observed for *P. roxburghii* on this aspect. On the NW aspect the maximum growing stock value (46.45 m^3 ha^{-1}) was observed under 30-40 cm diameter class, giving rise to a lesser total growing stock value (113.40 m^3 ha^{-1}) for *P. roxburghii* on this aspect. Although the maximum growing stock value (42.68 m^3 ha^{-1}) on the SE aspect was also recorded under 30–40 cm diameter class, the total growing stock value of *P. roxburghii* for all the diameter classes

(92.55 m^3 ha^{-1}) was not significant, because the growth of chir pine individuals was stunted on this aspect. The diameter class 20–30 cm gave the highest growing stock value (29.84 m^3 ha^{-1}) on the SW aspect of the SWCPF but the total growing stock value (67.76 m^3 ha^{-1}) was lowest amongst all the aspects (Figure 2) because of the higher diversity and more competitive growth of companion species on this aspect.

Soil analysis

The colour of the soils in the HHCPF varied from reddish-brown (SE aspect) to dark brown (remaining aspects), whereas, in the SWCPF it was predominantly whitish, because the Siwalik area is made up of Neogene sediments. The average ranges of moisture content (12.23 ± 1.30% on the SW aspect to 25.97 ± 1.93% on the NW aspect) and water holding capacity (17.29 ± 4.94% on the SW aspect to 51.32 ± 20.07 % on the NW aspect) were higher in the HHCPF than in the SWCPF (Table 2); these, high moisture content and water holding capacity, have supported the better growth of chir pine individuals in the HHCPF. The texture of the soils in these forests ranged from sandy loam (NE, NW and SW aspects of the HHCPF and NW and SE aspects of the SWCPF) to loamy sand (NE and SW aspects of the SWCPF) and silty loam (SE aspect of the HHCPF) indicating the coarse textured soils in these forests. The monospecific SW aspect of HHCPF was found to contain more acidic soils (pH 5.53 ± 0.06), whereas the pH of soils on other aspects of both forests was of less acidic to neutral range (Table 2).

Higher organic carbon contents (0.93 ± 0.51% on the SW aspect to 2.17 ± 0.21% on the NW aspect) were recorded in the HHCPF probably due to more water holding capacity of the soils; these values were less (0.72 ± 0.18% on the SE aspect to 1.09 ± 0.12% on the NW aspect) in the SWCPF. The maximum available phosphorous content was recorded in the soil of the SW aspect of the HHCPF (21.54 ± 9.72 kg ha^{-1}) and the minimum (7.82 ± 0.43 kg ha^{-1}) in the soils of the SE aspect of the SWCPF. The highest available potassium content (305.55 ± 53.36 kg ha^{-1}) was recorded in the soil of the SW aspect of the SWCPF due to the presence of *Anogeissus latifolia* and *Terminalia alata* (also supported by Upadhyay and Singh 1985) and the minimum (103.10 ± 40.16 kg ha^{-1}) on the SW aspect of the HHCPF, where chir pine was monospecific in nature. The available nitrogen percentage range was also higher (0.09 ± 0.03% on the SW aspect to 1.0 ± 0.009% on the NE aspect) in the HHCPF than in the SWCPF (0.04 ± 0.005% on the SE aspect to 0.09 ± 0.01% on the NW aspect): this high nitrogen content might have supported the higher growth of chir pine individuals in the HHCPF (Table 2).

Pine forests are seriously affected by violent fires, especially in the summer season, which result in a rapid deterioration of soil fertility and minimise the development of new species. According to Banerjee and Chand (1981), and Ghotz and Fisher (1982), burning in these forests leads to an immediate reduction of total organic matter and lowers the availability of phosphorus and potassium contents. However, the loss of soil carbon is potentially more serious than the loss of plant biomass carbon, because soil organic matter is especially important in sandy soil in improving soil water and nutrient status and minimising soil compaction (Sands 1983, Squire 1983).

In the Himalayan regions, due to heavy disturbances, either natural (such as landslides) or man-made (such as burning, selective exploitation of biomass and faulty

Table 2. Physico-chemical characteristics of the soils in the high Himalayan and Siwalik chir pine forests

Forest/ aspect	Colour	Moisture (%)	Water holding capacity (%)	Textural class	pH	Organic carbon (%)	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Available nitrogen (%)
NE HHCPF	10YR6/4	19.4±0.78	33.51±1.49	Sandy loam	5.76±0.15	1.03±0.22	13.27±1.35	231.31±17.74	1.00±0.009
NE SWCPF	10YR5/4	16.83±4.83	28.72±1.94	Loam sand	5.73±0.18	1.05±0.18	16.12±4.33	192.56±28.47	0.06±0.01
NW HHCPF	10YR4/3	25.97±1.93	51.32±20.07	Sandy loam	5.97±0.23	2.17±0.21	18.53±8.84	281.00±12.81	0.18±0.01
NW SWCPF	10YR5/4	11.17±1.48	25.53±1.57	Sandy loam	5.90±0.10	1.09±0.12	19.06±2.68	213.99±83.53	0.09±0.01
SE HHCPF	5YR4/4	18.87±0.87	31.65±2.39	Silt loam	5.87±0.07	1.12±0.22	16.67±3.86	204.66±83.76	0.91±0.01
SE SWCPF	10YR4/3	10.90±0.66	28.68±2.35	Sandy loam	6.03±0.09	0.72±0.18	7.82±0.43	116.21±6.16	0.04±0.005
SW HHCPF	10YR5/4	12.23±1.30	17.29±4.94	Sandy loam	5.53±0.06	0.93±0.51	21.54±9.72	103.10±40.16	0.09±0.03
SW SWCPF	10YR8/2	9.67±1.01	23.12±1.76	Loam sand	6.27±0.15	0.96±0.27	11.89±2.12	305.55±53.36	0.08±0.02

- HHCPF = high Himalayan chir pine forest
- SWCPF = Siwalik chir pine forest
- NE = northeast aspect
- NW = northwest aspect
- SE = southeast aspect
- SW = southwest aspect

management practices), the chir pine has widened its area markedly towards higher as well as lower elevations, and has now been stabilised as the most extensive community. According to Singh and Singh (1987), the presence of chir pine in Siwalik areas does not conform to the general pattern along the elevational gradient as determined by climate. The maximum dispersion of dominant *P. roxburghii* individuals under different diameter classes in the high Himalayan chir pine forests indicates that the species is in consonance with the climatic conditions prevalent over here, but in the Siwalik chir pine forests the limited distribution of *P. roxburghii* under different diameter classes suggests that this species is not suited to these areas due to its poor regeneration potential and suppressed growth.

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