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Weeds of Himalaya in Winter Crops*

N. P. MELKANIA*** AND J. S. SINGH**

Abstract. The present communication is an account of weed flora in winter crops of Western Himalaya (Kumaon and Garhwal), ranging from outer foot-hills to sub-alpine regions (altitude 700 m to 3,150 m above MSL). Out of 39 species, 34 species of 30 genera of 15 families belong to dicots and 5 species of 4 genera belong to 1 monocot family. Asteraceae (7), Brassicaceae (5), Poaceae (5), Leguminosae (4) and Papaveraceae (3) contribute about 61.54% to the total weed species. The associations of weeds in different crops have been emphasised with respect to phenology, habit and occurrence. The increasing intensity of the weeds can be prevented by uprooting them before the crop matures.

INTRODUCTION

Clark (1898), Hooker (1907) and Chatterjee (1939) classified Himalayas into two distinct botanical regions, viz. Western Himalaya and Eastern Himalaya. The former was further classified as the lower or outer Himalayas (elevation 1,250 m) with a tropical to temperate climate, the middle or central Himalayas (altitude 1,250 m to 1,850 m) having a moist and dry temperate climate and the higher or inner Himalayas (elevation 1,850 m to 8,000 m) with sub-alpine climate that culminates to large number of snowy peaks above 8,000 m having arctic or alpine climate (Wadia, 1919). Out of 52,81,408 ha reported land, only 13.21 per cent of land is under agriculture in Kumaon and Garhwal divisions. About 64.51 per cent of the latter is sown under winter crops (Anon., 1981). The introduction of new, high-yielding varieties of crops require comparatively higher moisture and fertilisation which also facilitates vigrous growth of weeds. In order to achieve better crop with maximum yields and effective weed control, the information about the crop-weed associations, phenology and other eco-taxonomical details are of paramount importance. These details are alltogether absent in the botanical accounts of the region (Kashyap, 1925; Gupta, 1968). Present study, therefore, is an attempt on the eco-taxonomical studies of winter weeds in Western Himalaya.

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There was no significant variation due to weed control treatments. But uptake was significantly influenced due to variation in time and dose of metoxuron. Application of metoxuron at 1.75 kg/ha and at 25th day helped in higher uptake.

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MATERIALS AND METHODS

The winter crops are planted during October–November and reaped in May–June. Wheat (*Triticum aestivum* L.) is the chief crop of this reigon. Hulled barley (*Hordeum vulgare L.*) and hulless barley (*H. himalayanse* Coeleste) are considered as secondary cereals. Moreover, cultivation of hulless barley is much more popular among high–altitude farmers. The oil-seed crops (lower and middle Himalayas) are represented by mustard (*Brassica compestris* L.), toria (*B. compestris* var. *toria* Duthie and Fuller), leaf mustard (*B. juncea* Coss.), Rare or pili sarson (*B. compestris* var. *glauca* Roxb.) whereas gram (*Cicer arietinum* L.), pea (*Pisum sativum L.*) and lentil (*Lens esculenta* Moench.) are sown as pulse crops, generally cultivated with wheat. Recently, mustard is also being cultivated as monocrop in high altitude areas of Johar valley upto Milam (altitude 4,000 m approximately). The cultivation of fodders in fields is not favoured by villagers, but, cultivation of oat (*Avena sativa* L.) is practiced at some places.

To study the weeds during October to June, extensive explorations of cultivated fields were made from 1978 to 1981. The weed species were collected, taking a note on eco–taxonomical features neamely habit, occurrence, crop-weed association, time of flowering and fruiting and phenology, and identified by comparing characteristics of the type specimens with the literature (Hooker, 1885; Collett, 1902; Raizada and Saxena, 1978).

RESULTS AND DISCUSSION

A total of 39 species belonging to 16 angiospermic families have been recorded from crop–fields during winter season located at different topographic and altitudinal situations (Table 1). The number of weeds was found highest in wheat (37) followed by those in barley (22), pulses (14) and hulless barley (9). *Ageratum conyzoides* L., *Capsella bursa–pastoris* (L) Medic., *Fumaria parviflora* Lamk., *Poa annua* L., *P. pratenis* L., *Stellaria crispitata* Wall. and *S. media* L. were found to be associated with all the winter crops. *Chenopodium album* L., *Fumaria parviflora*, *Phalaris minor* Retz., *Ranunculus arvensis* L. and *Stellaria media* were dominant. The Asteraceae (7), Brassicaceae (5), Poaceae (5), Leguminosae (4) and Papaveraceae (3) have contributed maximum (61.54%) to weed population.

The statistical synopsis of the weeds indicated that the number of dicots (34 species of 30 genera of 15 families) is greater than the monocots (5 species of 4 genera of 1 family). The ratios of monocots and dicots were estimated as 1 : 0.06 at families, 1 : 0.13 at genera and 1 : 0.15 at species level, respectively.

The number of weeds was maximum in wheat. This is perhaps due to the fact that wheat is cultivated in much diverse agro-climatic areas of different relief than the other winter crops. This provides suitable bioclimatic substratum to each weed species accordingly. Sharma (1978) while studying the weeds of *rabi* crops in Punjab have also noticed maximum number of weeds (55) with wheat. *A. conyzoides*, *Galinsonga parviflora* Cav., *Oenothera rosea* Ait., *Poa annua* and *P. pratensis* were found

Table 1. Association of the weeds in various winter crops

Sl. No.	Weed species	CROPS: Wheat	Barley	Halles barley	Pulses	Flowering and Fruiting	Remark (Habit, Occurrence)
1	2	3	4	5	6	7	8
1.	*Ageratum conyzoides* L.	+	+	+	+	All, Aug.-Sept.	YH, F
2.	*Amaranthus spinosus* L.	+	–	–	–	May-Aug.; Sept.-Oct.	AH, R
3.	*Anagaleis arvensis* L.	+	+	–	–	Feb.; Mar.-June	AH, F
4.	*Arabis glabra* Bernch.	+	+	–	–	May-June; Aug.	AH, F
5.	*Argemone mexicana* L.	+	–	–	–	Mar.-April; May	AH, VR
6.	*Avena fatua* Hook. f.	+	+	–	–	Mar.; May	AH, R
7.	*Capsella-bursa-pastoris* (L.) Medic.	+	+	+	+	Feb.-July; May-Oct.	AH, C
8.	*Cardamine impatiens* L.	+	+	–	–	Mar.; May	AH, F
9.	*Chenopodium album* L.	+	–	–	–	Mar.; May-June	AH, D
10.	*C murale* L.	+	+	–	–	Mar.; May	AH, F
11.	*Companula colorata* Wall.	–	+	+	–	May-June; Aug.-Sept.	AH, R
12.	*Crepis foetida* L.	+	+	–	+	Apr.; June	AH, F
13.	*C. japonica* Benth.	+	–	–	+	Feb.-Mar.; May-June.	AH, F
14	*Epilobium sp.* L.	+	–	–	–	May-June; Sept.	AH, R
15.	*Euphorbia hirta* L.	+	–	–	–	All; Aug.-Sept.	AH, R
16.	*Fumaria parviflora* Cav.	+	+	+	+	Jan.-Mar.; April-May	AH, D
17.	*Galinsoga parviflora* Cav.	+	+	–	+	All; All.	YG, F
18.	*Geranium neplanese* Sweet.	–	+	+	–	Apr.-May; July-Aug.	AH, VR
19.	*G. ocellatum* Camb.	+	+	–	–	Mar.; May-June	AH, F
20.	*Lathyrus aphaca* L.	+	–	–	+	Mar.-Apr.; Apr.-May	AH, F
21.	*Launaea nudicaulis* Less.	+	–	–	–	Mar.; May	AH, R
22.	*Lepidium virginicum* L.	+	+	–	–	Feb.-Apr.; May-Sept.	AH, F
23.	*Linum sp.* L.	+	–	–	–	Mar.; May	AH, R

1	2	3	4	5	6	7	8
24.	*Lolium temulentum* L.	+	+	–	–	Feb.–Apr.; May–June	AH, F
25.	*Mazus rugosus* Lour.	+	+	–	+	Mar.; May–June	AH, F
26.	*Medicago lupulina* L.	+	–	–	–	Apr.; June	AH, R
27.	*Melilotus indica* All.	+	–	–	+	Mar.; May	AH, R
28.	*Oenothera rosea* Ait.	+	–	–	–	May–July; Aug.–Sept.	YG, R
29.	*Papaver dubium* L.	+	+	–	–	Apr.; May–June	AH, F
30.	*Phalaris minor* Retz.	+	–	–	–	Mar.–Apr.; May	AH, D
31.	*Poa annua* L.	+	+	+	+	All; All	YH, C
32.	*P. pratensis* L.	+	+	+	+	All; All	YH, C
33.	*Renunculus arvensis* L.	+	–	–	–	Feb. Mar.; April	AH, D
34.	*Stellaria crispata* Wall.	+	+	+	+	Feb.–Apr.; May-June	AH, F
35.	*S. media* L.	+	+	+	+	All; All	AH, PD
36.	*Sisymbrium strictum* Hook. f. & T.	+	+	–	–	Apr., June	AH, C
37.	*Sonchus asper* Gars.	+	–	–	+	Mar., May	AH, F
38.	*Vernonia cinerea* Less.	+	–	–	–	Mar., May	AH, R
39.	*Vicia hirsuta* Gray.	+	–	–	–	April, May–June	AH, C

Abbreviations :

+ = Present ; – = Absent ; A = Annual ; Y = Year round ; H = Herb ;

VR = Very rare ; R = Rare ; F = Frequent ; C = Common ; D = Dominant ;

PD — Predominant.

growing successfully round the year owing to suitable microclimate at various pockets in crop fields and waysides (Melkania and Sharma, 1980). It is also evident that most of the weeds complete their life earlier than crops, thus, act as bio-pollutents of the next year's crops. Further, more *C. album*, *C. murala* L., *Lolium temulentum* L., *Avena fatua* Hook. L. and *Vicia hirsuta* Gray mature simulataneously with the crop, resulting in the contamination of seeds for subsequent sowing. Therefore, such weeds must be uprooted prior to crop maturation period.

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Application of Aerial Photo-Analysis for Assessment of Vegetation in Kumaun Himalaya. I. Ranibag to Naina Peak—Kilbari

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Out of a total of 11900 ha assessed through aerial photo-analysis, 27.6% was under non-forest landuse and 72.4% was covered by forest of one type or the other. Forests with >40% crown density were recorded in 32.1% of the total study area and only 16.3% land had forests with >60% crown density.

Key Words: Photo-analysis, Landuse, Crown density, Himalayan forest

Introduction

The pressure on land resources has increased many-fold in recent years as a result of ever-increasing population and associated demands. This calls for a rational, scientific management of natural resources. Information needs for planning such as management strategy comprising reliable, quick and comprehensive inventories. This is particularly important for the Himalayan region which harbours a network of catchments so vital for the entire country.

The use of remote sensing techniques offers increased potentialities and new ways for solving resource problems, compared to traditional, expensive and time-consuming field surveys (Schanda 1976). Aerial photography has been extensively used as a remote sensor for mapping and estimating the natural resources (Young et al. 1963, Wagner 1963, Swanson 1964, Kummer 1964, Waelti 1970, Garofalo & Wobber 1975). According to Khosla (1978), aerial photography was first used in India in 1920, in a survey experiment; later on in 1923-24 air survey of Irrawadi delta forest in Burma, which was a part of British India was conducted; and as early as in 1926 aerial photography was used as a technique for flood assessment of river Indus at Dera Ismail Khan, then a part of undivided India.

Use of aerial photographs in mapping and assessing the vegetation has not gained sufficient momentum in India, however. Bhaskara Rao and Vaidyanadhan (1975) studied the coastal features in Andhra Pradesh, Rao (1975) commented upon the origin of Renuka lake and Gautam (1976) classified urban landuses through aerial photo-interpretation.

In the present study, photo-analysis technique is used to assess the vegetation and landuse pattern of parts of Kumaun Himalaya.

Study Area

Location

The entire study area—Ranibag to Naina peak—Kilbari transect,(29°15′–29°26′30″N lat. and 79°30′ – 79°40′ E long., encompassing an altitudinal range of 600–2600 m)—lies in the hilly part of the Naini Tal district. The Siwaliks form the lower extremity and the Naina peak, the highest peak of lesser Himalaya, constitutes the upper extremity of the transect. The unique feature of this tract is that in a crow flight distance of only about 19 km the mountains rise sharply from 600 m to 2600 m above the mean sea level.

Geology

Geology of the area has been described by Hukku et al. (1974) and Fuchs and Sinha (1974). The area constitutes two main groups of rocks—Siwalik and Krol—and is demarcated by Main Boundary Thrust (MBT) near the township of Jeolikote. The Siwalik group comprise white grey coarse-grained sand stone interbedded with purple slates at places.

Climate

The mean monthly temperature varies from 5.3°C (in January) to 18°C (in June) at Naina peak—Kilbari, and from 12°C (in December) to 27°C (in June) at Ranibag. Total annual rainfall ranges from 2056 mm at Ranibag to 2527 mm at Naina peak—Kilbari hills.

Methods

Vertical aerial photographs (1:40,000) taken in 1973 by the Survey of India were interpreted through the following sequential steps:

(*i*) A reconnaissance of the study area was made with aerial photographs and topographic map, and a photo-analysis key was prepared (table 1).

(*ii*) Photomosaic was constructed and boundary of study area was marked on the aerial photographs. Photographs were prepared for photo-analysis by marking principal points, conjugate principal points, flight lines, and finally drawing the effective areas with the help of mirror stereoscope.

(*iii*) By using double scanning stereoscope and on the basis of pre-prepared photo-analysis key, different landuse categories were delineated on the aerial photographs with water colour. These delineations were verified through field checks. Details of delineated photographs were then transferred to a base map (1:50,000) prepared from topographic sheet, using aero-sketchmaster.

(*iv*) Forests were delineated using crown characteristics (Tomar & Maslekar 1974). Each forest type was sub-divided into five classes on the basis of crown density: (*i*) $\leqslant$ 20%; (*ii*) 21–40%; (*iii*) 41–60%; (*iv*) 61–80% and (*v*) above 80%. These classes were determined by comparing the crown cover as seen on the aerial photographs with the density chart.

(*v*) These crown density classes were then calibrated to the present field conditions by collecting random ground truth data from given forest types. The readjusted values are used in the present paper.

(*vi*) The area of different landuse categories and of each crown density class

Table 1 *Key for interpretation of panchromatic black and white aerial photographs*

Landuse category	Features	*Tonal grades	Texure	Patterns	Shape	Size	Symbol
NON-FOREST							
Eroded lands	Generally confined to steep slopes, soils and vegetation stripped off	1	M	I	I	V	E
Waste lands	Uncultivated lands having grasses; some times with rock outcrops	2 & 3	S to M	I	I	V	W
Habitation	Residential buildings easily distinguishable	1 & 2	C	R	I	V	H
Main roads	Linear structures generally terminate in the inhabited areas	1	S	R	S	V	
Water bodies	Rivers exhibiting meandering course with varying width; lakes—no definite	4 & 5	S	I	I	I	
Agriculture	Mainly terrace cultivation	2 & 3	S to M	R	I	I	A
FOREST							
Shorea robusta	Confined to foot-hills	5	C	I	CC	U Can	S
Mixed Sal	*P. roxburghii* and *S. robusta* present; latter had greater proportion	2 & 5	C	I	CC (*S. robusta*) GC (*P. roxburghii*)	V Can	SM
Mixed Pinebroadleaf	Overlapping of various crown shapes with distinct crown of *P. roxburghii*	2,3 & 4	C	I	OC	V Can	PM
Pinus roxburghii	Ground surface clearly visible expressing light tone	2	C	EDS	GC	U Can	P
Quercus leucotrichophora	Generally found in moist areas	3 & 4	C	I	G	V Can	QL
Cupressus torulosa	Found on steep slopes and relatively high elevations	4	C	EDS	CC	U Can	C
Mixed high altitude oak	Found at higher altitude than Q. *leucotrichophora* forest	4	C	I	VC	V Can	QM
Scrub vegetation	Ground surface depicting a carpet-like structure	2	C	I	I	I	SC

**Tonal grades*: The tone depicted by different landuse categories in the aerial photographs was classified in five grades: 1, being light, and 5, being dark—the successive increase in tonal grade number shows successive increase in darkness

C, Coarse; *C Con.*, Crown Conical; *C Cy*, Crown cylindrical; *EDS*, evenly distributed Canopy; *G*, globular; *GC*, Globular Crown; *I*, Irregular; *M*, Medium; *OC*, Overlapping Crowns; *R*, regular; *S*, smooth; *U Can*, uniform canopy; *V*, Varying; *VC*, varying crowns; *V Can*, varying canopy

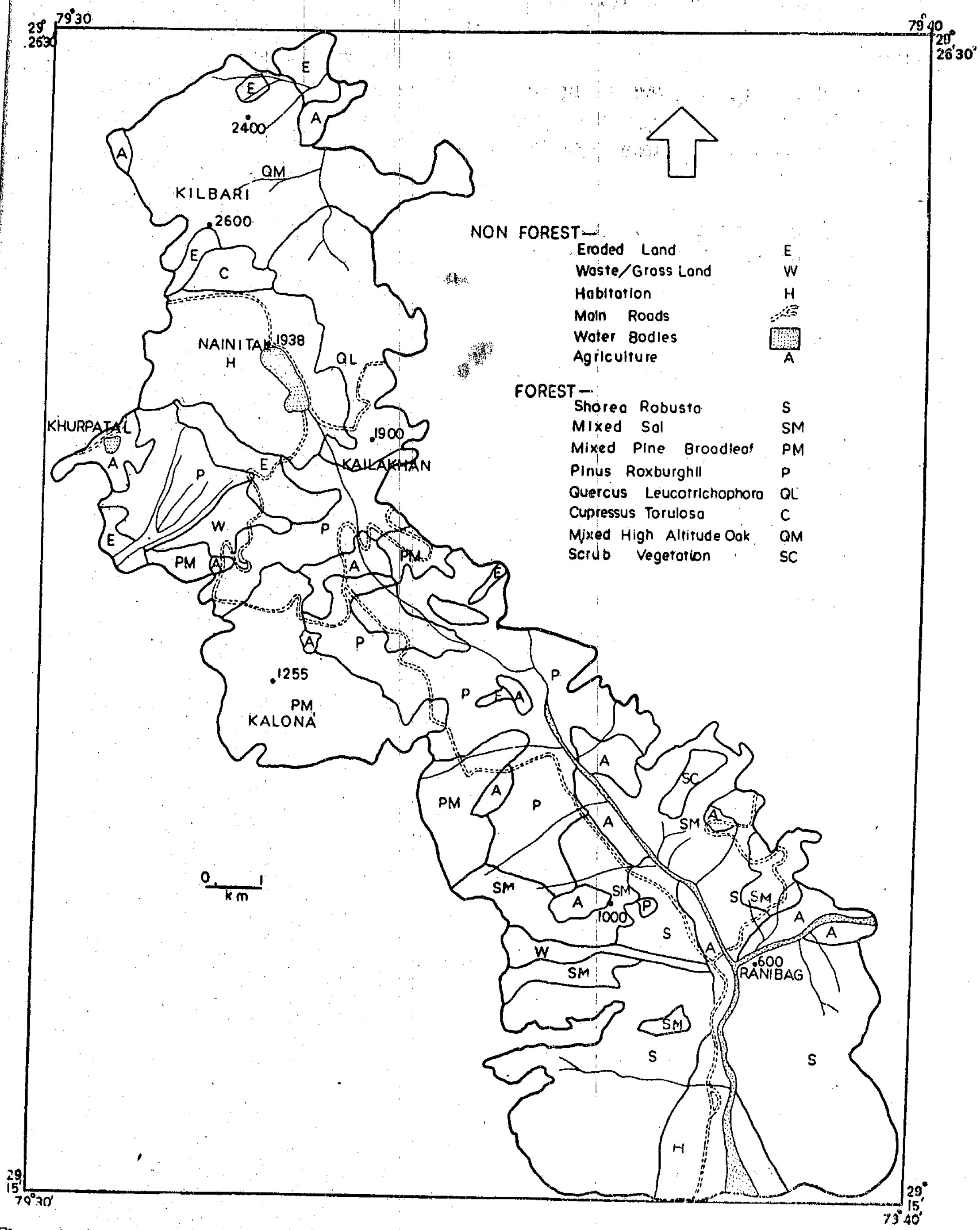

Figure 1 Map of vegetation and other landuses of the study area interpreted from aerial photographs. Altitudes of selected localities are given in meters

was estimated by standard dot-grids.

Results

The interpreted map is given in figure 1 and the area for different vegetation types and other landuses is estimated in table 2.

Non-forest Area

Total non-forest area accounted for 3281.2 ha, that is 27.6% of the total study area (11,900 ha). Within the non-forest landuses, 24.8% area was devoted to agriculture, which is 6.8% of the total study area. Habitation was recorded in 675 ha area, i.e. in 5.7% of the total area. The township of Naini Tal was mainly responsible for this non-forest landuse category. Major water bodies such as Naini Tal lake, Khurpa Tal lake, Balia river, Gola river and other streams were distinguishable on aerial photographs. Almost all the rivers and streams exhibited straight course in this mountainous region which suggests that they follow faults or fractures. Main roads in the study area accounted for 518.7 ha. Among other non-forest landuses, waste lands accounted for 3.5% of the total and 12.8% of the non-forest area, while eroded lands were spread over 406.2 ha. Both waste and eroded lands were more common in the upper half of this altitudinal transect, where forests of *Pinus roxburghii* Sarg., *Quercus leucotrichophora* A. Camus, *Cupressus torulosa* Don. and mixed high altitude oak predominated. Some of the potential landslide prone areas were situated in south-west and north-west of Naini Tal town.

Table 2 *Summary of vegetation and landuse*

Landuse	Area (ha)	% of forest/non-forest area	% of total area
NON-FOREST			
Eroded lands	406.2	12.4	3.4
Waste lands	418.8	12.8	3.5
Habitation	675.0	20.5	5.7
Main roads	518.7	15.8	4.4
Water bodies	450.0	13.7	3.8
Agriculture	812.5	24.8	6.8
Total non-forest	3281.2		27.6
FOREST			
S. robusta	2068.8	24.0	17.4
Mixed Sal	1025.0	11.9	8.6
Mixed Pine-broadleaf	1437.5	16.7	12.1
P. roxburghii	1593.8	18.5	13.4
Q. leucotrichophora	1087.5	12.6	9.1
C. torulosa	112.5	1.3	0.9
Mixed high altitude oak	1175.0	13.6	9.9
Scrub vegetation	118.7	1.4	1.0
Total forest	8618.8		72.4
Grand total	11900.0		

Forest Area

Shorea robusta Gaertn. f. forest (figure 2): A total of 2068.8 ha, i.e. 24% of the total forest area or 17.4% of the total study area, was covered by *Shorea robusta* forest (table 2) between 300 and 900m altitudes. Entire territory of this forest was dominated by a single tall species, viz., *S. robusta*. The field checks revealed *Mallotus philippensis* (Lam.) Mueller Arg., *Syzygium cumini* Linn., *Ehretia laevis* Roxb. and *Terminalia tomentosa* Wt. and Arn. as companion species.

Although all five crown density classes were represented, 63.5% of the land was covered by forest with ⩽ 40% crown density and 19.3% with forest of > 80% crown density (table 3) which occurred in the vicinity of the confluence of rivers Balia and Gola.

Speaking of the total study area, 6.4% had *S. robusta* forest with crown density > 40% and 4.3% with crown density > 60% (table 4).

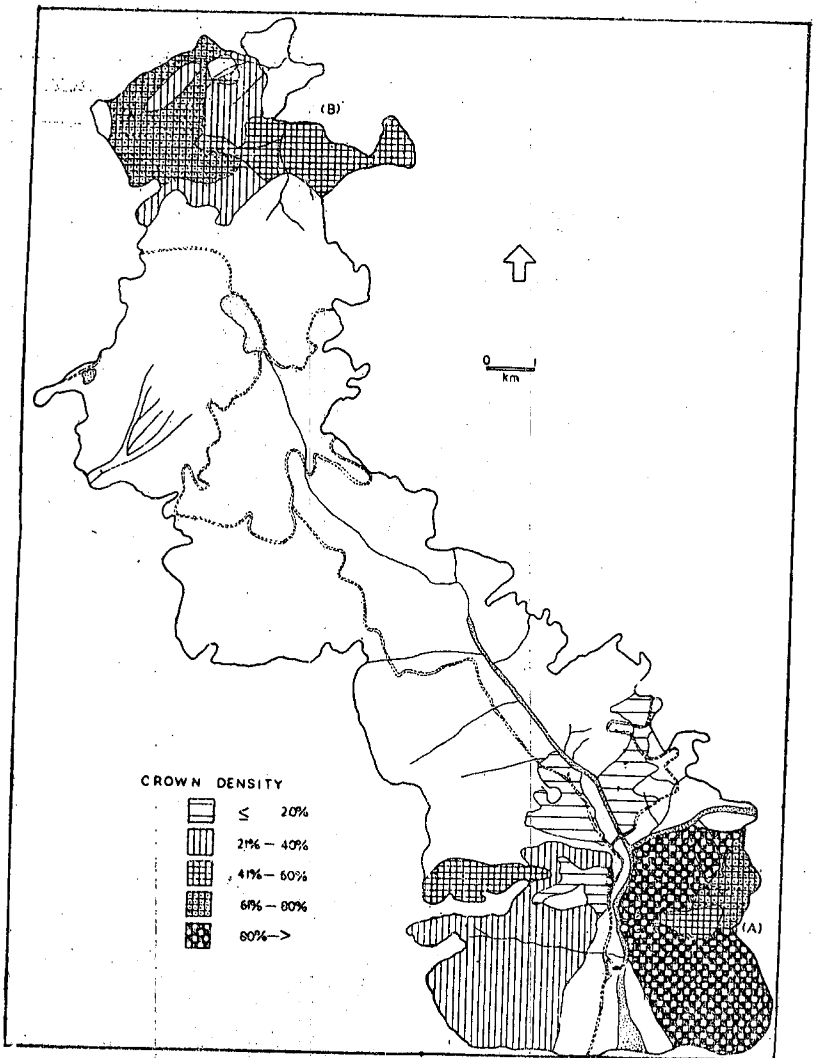

Figure 2 Crown density and distribution of (A) *Shorea robusta*, and (B) mixed high altitude oak forest

Table 3 *Area in each crown density class within different forest types*

Forest	Crown density ≤20% Area (ha)	≤20% %	21–40% Area (ha)	21–40% %	41–60% Area (ha)	41–60% %	61–80% Area (ha)	61–80% %	>80% Area (ha)	>80% %
S. robusta	462.5	22.4	850.0	41.1	243.8	11.8	112.5	5.4	400.0	19.3
Mixed Sal	531.2	51.8	118.8	11.6	150.0	14.6	225.0	22.0	—	—
Mixed pinebroadleaf	306.3	21.3	256.2	17.8	281.3	19.6	—	—	593.7	41.3
Pinus roxburghii	293.8	18.4	800.0	50.2	500.0	31.4	—	—	—	—
Q. leucotrichophora	331.3	30.5	275.0	25.3	256.2	32.7	125.0	11.5	—	—
Cupressus torulosa	112.5	100.0	—	—	—	—	—	—	—	—
Mixed high altitude oak	—	—	343.7	29.3	343.7	29.3	487.6	41.4	—	—

Mixed Sal (*S. robusta—P. roxburghii*) *Forest* (figure 3): The area covered by this forest was 1025 ha (8.6% of the total area mapped within the altitudinal range 900 to 1200m. The dominance of *S. robusta* in valleys

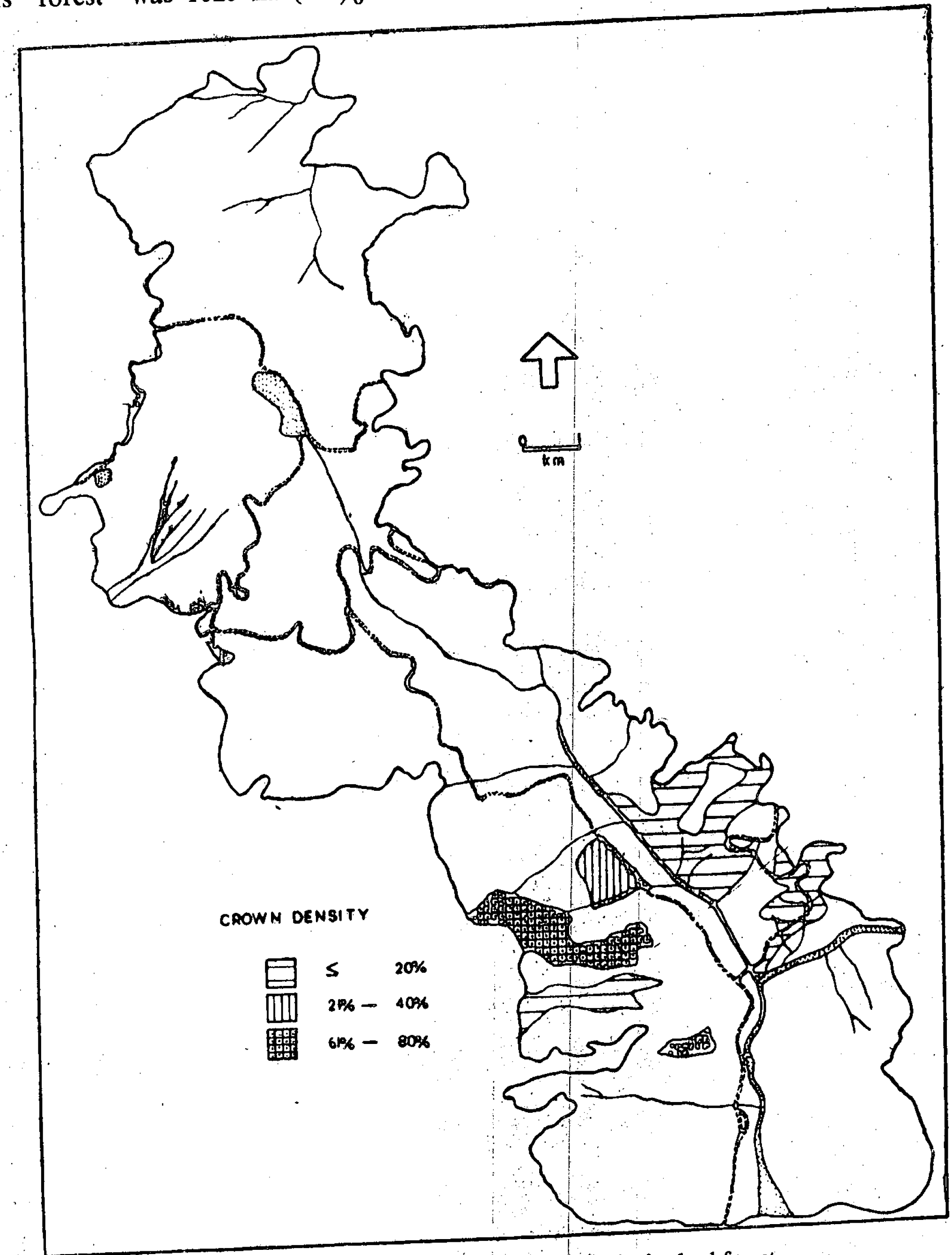

Figure 3 Crown density and distribution of mixed sal forest

and of *P. roxburghii* on ridge tops was recognizable from the aerial photographs. Other important associated species were *Toona ciliata* Roem. and *M. philippensis.*

Nearly half (51.8%) of its total area i.e. 513.2 ha was covered with a forest with ⩽ 20% crown density (table 3). Forest with crown density > 80% was altogether absent.

Only 3.1% of the total study area had this forest with crown density > 40% and 1.9% with crown density > 60% (table 4). In certain areas this forest overlaps the altitudinal range of *Shorea robusta* forest.

Mixed Pine-broadleaf Forest (figure 4): This forest type covered 1437.5 ha, constituting 12.1% of the total area

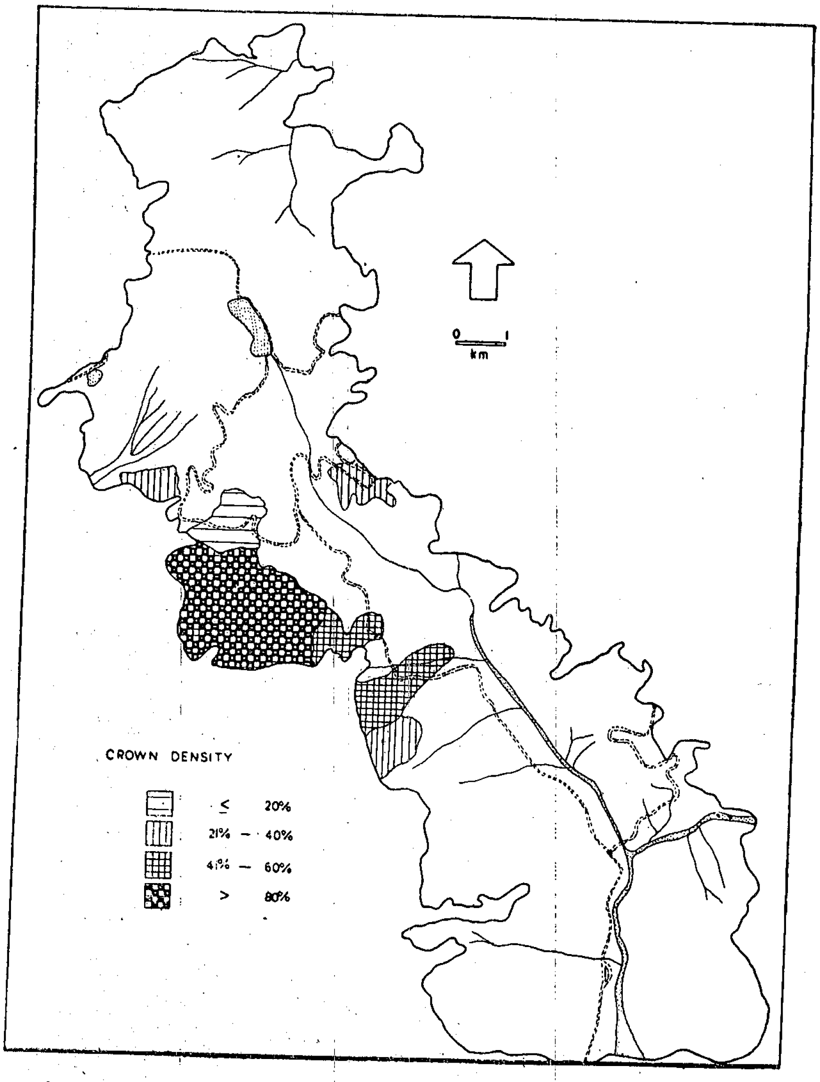

Figure 4 Crown density and distribution of mixed Pine-broadleaf forest

studied (16.7% of total forested area). Extending from 1200 to 1500m the forest was dominated by *Pinus roxburghii* with several associated broadleaf species, such as *Quercus leucotrichophora*, *Syzygium cumini* and *Myrica sapida* Wall. *Pinus roxburghii* and broadleaf species, in general, were distinguishable from each other on the aerial photographs.

In 41.3% of its aerial extent crown density was > 80%. This indicated that it is the finest forest found within the study area (table 3).

Pinus roxburghii Forest (figure 5): This forest occupied 1593.8 ha in an altitudinal range which overlapped with that of mixed pine-broadleaf forest towards the lower end (1200–1500 m) and *Quercus leucotrichophora* forest

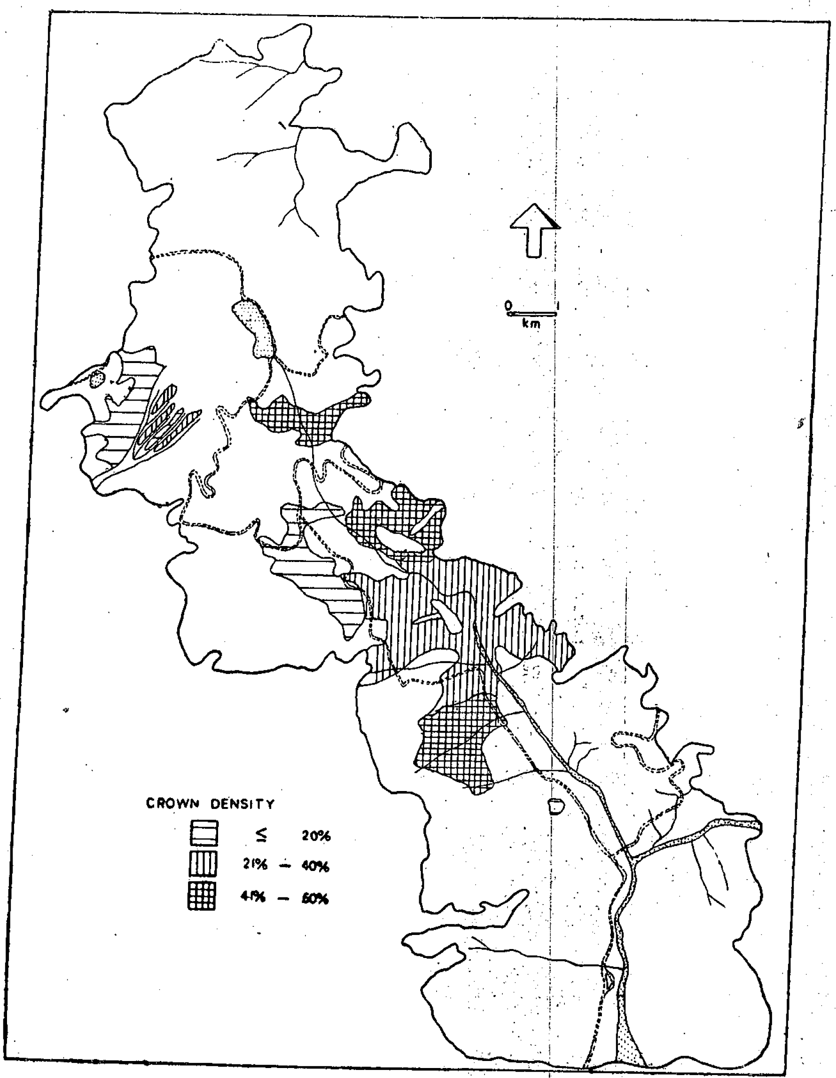

Figure 5 Crown density and distribution of *Pinus roxburghii* forest

towards the upper end (1700–2000 m). Throughout the territory of this forest (13.4% of the total area studied) the single tall tree species, viz., *P. roxburghii* was dominant.

About two-third of the forest area exhibited a crown density of 40% or less and the remaining one-third had a crown density between 41–60% (table 3). The relative dense crown classes (>60%) were not present. Only 4.2% of the total study area was represented by *Pinus roxburghii* forest with crown density > 40% (table 4).

Table 4 *Per cent of total study area with forests of >40% and > 60% crown density classes*

Forest	Per cent area with >40% crown density	Per cent area with >60% crown density
S. robusta	6.4	4.3
Mixed Sal	3.1	1.9
Mixed pine-broadleaf	7.4	5.0
P. roxburghii	4.2	—
Q. leucotrichophora	4.0	1.0
C. torulosa	—	—
Mixed high altitude oak	7.0	4.1
Total	32.1	16.3

Quercus leucotrichophora Forest (figure 6): Within the altitudinal range 1700–2000m, this forest covered 1087.5 ha (9.1% of the total area) (table 2). Though *Quercus leucotrichophora* was predominant, scattered individuals of conifers, such as *Pinus roxburghii* and *Cedrus deodara* Loud. were also recognizable on the aerial photographs. Field checks revealed that certain broadleaf species such as *Myrica sapida*, *Rhododendron arboreum* Sm., *Quercus floribunda* Lindl. and *Acer oblongum* Wall. were also present in this forest, though they were unrecognizable on aerial photographs.

Within this forest type, area under crown density class 41–60% was maximum (32.7%) and that under class 61–80% minimum (11.5%) (table 3).

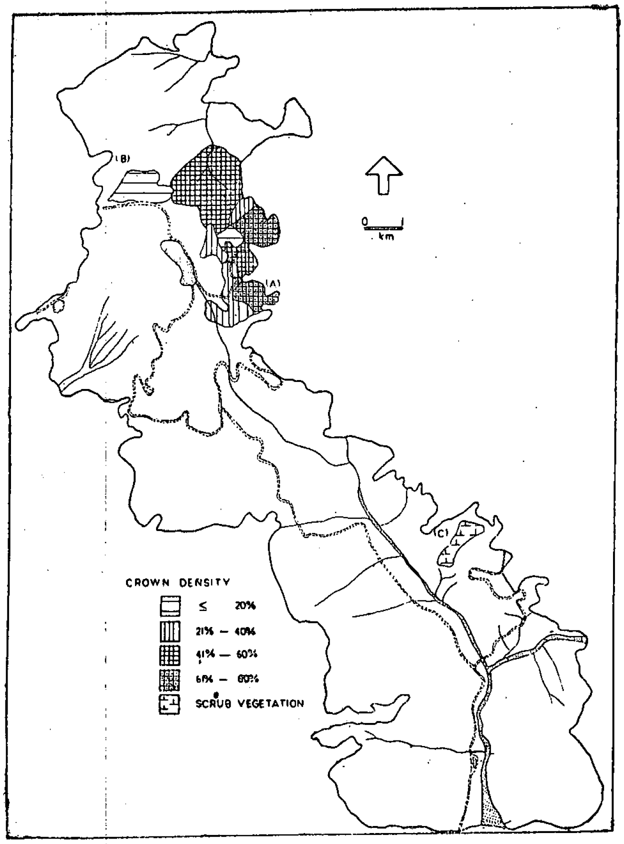

Figure 6 Distribution of (A) *Quercus leucotrichophora* forest, (B) *Cupressus torulosa* forest, and (C) scrub vegetation

Only 4% of the total mapped area had *Quercus leucotrichophora* forest with crown density > 40% and only 1% with crown density >60% (table 4).

Cupressus torulosa Forest (figure 6): A small patch of *Cupressus torulosa* forest (112.5 ha) was noticed in the north-west of Naini Tal town just below the Naina peak, between 2100 to 2400m altitude. The dominance of single tree species, viz., *Cupressus torulosa* was clearly visible on the aerial photographs, and the entire forest area was in the category of crown density ⩽ 20%. A number of land-slide scars were distincly visible.

Mixed High Altitude Oak Forest (figure 2): The mixed high altitude oak forest accounted for 9.9% (1175 ha) of the total study area (table 2). It was difficult to make any visual differentiation among various *Quercus* species as the gray level appeared to be the same because of low resolution of aerial photographs in 1:40,000 scale. But they together exhibited crown cover characteristics which rendered the separation of this forest possible from others (table 1).

Quercus lanuginosa D. Don., *Quercus semecarpifolia* Sm., *Quercus floribunda* and *Quercus leucotrichophora* were representative oaks of this forest. Compared to *Quercus leucotrichophora* forest (1700–2000 m), this mixed oak forest was located at higher altitude (2100–2600m).

Within this type, 29.3% area was covered by forest with crown density 21–40%, 29.3% area with crown density 41–60% and 41.4% area with forest of crown density 61–80%. Crown density classes ⩽ 20% and > 80% were absent (table 3). A total of 7% of the study area had this forest with > 40% crown density and 4.1% with > 60% crown density.

Scrub Vegetation (*figure 6*): The scrub vegetation covered only 1% of the total study area (table 2) and was present between forest and agricultural lands. No species could be identified on aerial photographs but ground checks revealed the presence of *Lantana camara* Linn., *Murraya koenigii* Spreng., *Murraya exotica* Linn. and *Clerodendrum viscosum* Vent.

Discussion

Although the total forested area accounted for nearly three-fourth of the study area, forests with crown density >40% or >60% accounted for respectively only 32.1% and 16.3% of the total area (table 4). Crown density above 80% was recorded only in two forest types that were located in the lower half (600–1500 m) of the altitudinal range. The generally poor crown density in 67.9% of the land area bear testimony to over exploitation.

A representation of compositional relationship among 52-forest stands of this area using polar ordination method (Bray & Curtis 1957) revealed that there was no clear cut cluster of stands, so that they heighlight continuity rather than discontinuity of vegetation in space (Tewari 1982). The ordination of vegetation identified major arbitrary community types of the present study. The dividing lines between any two communities were not distinct because a few stands intermixed with those of adjacent community. Ordination results also confirmed the altitudinal patterning of vegetation from absolute dominance of *Shorea robusta* below about 900 m to mixed high altitude oak forest above 2100 m with several oak species viz., *Quercus lanuginosa*, *Q. semecarpifolia*, *Q. floribunda* and *Q. leucotrichophora*, revealed by the present study. According to Tewari (1982), on the first ordination axis the stands are differentiated primarily by the altitude they occupy, the *X* values (i.e. the first ordination axis) of stands increase with increasing altitude, lowest being for the stands located in the foot hills (*Shorea robusta*-dominated stands) and highest for the stands located within highest altitudinal belt (2100–2600 m), i.e. stands having mixed high altitude oaks. Thus owing to rapid altitudinal variations (600–2600 m in a crow flight distance of only 19 km), the change in environmental complex is sharp; the grading of one community into another rather than their discreteness is noticeable.

Interesting instances of encroachment of pine into oak forest were observed while collecting the ground truth data. For example, at Kailakhan at 1700–1800m elevation in crown openings of *Q. leucotrichophora* caused by heavy lopping a few pine trees got established. As a result of the seed broadcast from these mother trees and continued lopping and felling of the oak trees, young pine trees have established on the lower slopes. The area occupied by pine is now extending towards the upper slope. Tewari (1982) has reported that the lower slope stands of *Q. leucotrichophora* forest in the same locality were displaced too much from the rest of the stands in ordination field and came closer to the stands dominated by pure crop of *Pinus roxburghii*. This indicates that in this forest pine element is gradually increasing at the expense of *Q. leucotrichophora*.

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