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RESTITUTION OF REPRODUCTIVE BIOMASS OF OVERSTOREY TREE SPECIES IN CERTAIN FORESTS OF KUMAUN HIMALAYA

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Restitution of reproductive biomass in seven forests of Kumaun Himalaya was estimated. Two forests were dominated by *Shorea robusta*, two by *Pinus roxburghii* and the remaining three by *Quercus* spp. Reproductive organs of nine tree species were captured in the litter traps; of these seven were angiosperms and two gymnosperms. The highest reproductive output was recorded for the two oak dominated forests, followed by the pine forest, whereas the lowest output was recorded for pine-mixed broadleaf forest. The total reproductive output ranged between 81.16 and 3.6 g m^{-2}. These account for 11.09 to 1.03% of the total litter fall in these forests.

Kumaun Himalaya represents a great diversity of forest types, but incidentally no information is available on their genetic resources. An attempt has been made in this paper to project information on the fall of reproductive biomass from overstorey forest-tree species in seven forests located along an altitudinal gradient in Kumaun Himalaya.

STUDY SITES AND CLIMATE

The sites selected in Kumaun Hills cover three longitudinal belts located between 29° 7′–29° 38′ N lat. and 79° 27′–79° 48′ E long, encompassing an altitudinal gradient from 300 to 2200 m: the Bhabhar – a sub-mountainous and piedmont belt in the foothills; the outer Himalayan Siwalik belt, 900-1500 m high, built up of late tertiary sedimentaries, which exhibit a rugged and restive topography characterized by steep hill-slopes and deep valleys; and the Lesser Himalaya, separated from the Siwalik by the Krol Thrust (main boundary fault) in the Lesser Himalaya, 1500 to 2500 m high (Valdiya, 1980). Rainfall, temperature and dominant species are given in Table 1. The climate varies from monsoon sub-tropical to monsoon temperate. The two sal (*Shorea robusta* Gaertn. f.) forests lie in the monsoon sub-tropical climate, characterized by a hot summer and cool winter, and the three oak-dominated forests lie in monsoon temperate climate, characterized by a warm summer and cold winter, experiencing frequent frost and snow. The two pine (*Pinus roxburghii* Sarg.) dominated forests lie in between these two extremes of climate. The annual cycle is generally divided into a rainy (July –October), a winter (November–February) and a summer (March–June) season as described by Pandey & Singh (1981) and Saxena & Singh (1982).

METHODS OF STUDY

Stand structure, viz., species composition, density,

Table 1. *Site characteristics of different forests*

Site	Altitude (m)	Average annual Rainfall (mm)	Average tempera-ture (°C)	Forest type	Dominant species
Chorgalia	329	2076	23	Sal oldgrowth forest	*Shorea robusta*
	350	2076	23	Sal coppice forest	*Shorea robusta*
Kalona	1350	2005	18	Pine-mixed broadleaf forest	*Pinus roxburghii* *Quercus leucotrichophora* *Myrica esculenta*
Baldiyakhan	1750	2185	16	Pine forest	*Pinus roxburghii*
Ranikhet	1850	1313	16	Mixed oak-pine forest	*Quercus leucotrichophora* *Pinus roxburghii*
Kilbury	2150	2508	13	Mixed oak, Rianj-dominated forest	*Quercus lanuginosa*
	2250	2508	13	Mixed oak, Tilonj-dominated forest	*Quercus floribunda*

basal cover and importance value index (IVI) was quantified for each site using standard phytosociological techniques (Curtis & McIntosh, 1951; Muller-Dombois & Ellenberg, 1974). During 1981-82, litter input was measured by placing 10 wooden litter traps (50 × 50 × 15 cm) randomly on the forest floor in each forest. Litter was collected at monthly intervals in polyethylene bags and sorted into components such as leaf, wood, bark, flower and fruit, for analysis. The material was oven dried at 80° C to constant weight and data on fruit and flower fall were recorded.

RESULTS

Important phytosociological characters are given in Table 2. Among the various species, *S. robusta* (sal) in both sal forests, *P. roxburghii* in the pine-mixed broadleaf forest at Kalona and in the Baldiyakhan pine forest, *Quercus leucotrichophora* A. Camus. in the mixed oak-pine forest at Ranikhet, *Q. lanuginosa* Don (Rianj) in the Rianj-dominated mixed oak forest at Kilbury and *Q. floribunda* Lindl. (Tilonj) in the Tilonj-dominated mixed oak forest at Kilbury showed maximum density, basal cover and importance value index (IVI). The tree species diversity as represented by Shannon-Wiener information function (Shannon & Wiener, 1967) was maximum in the pine-mixed broadleaf forest at Kalona and lowest in the Baldiyakhan pine forest. The reverse was true for the concentration of dominance.

Table 2. *Phytosociological characteristics of different forests*

Forest type	Species	Density (tree ha^{-1})	Total basal cover (m^2 ha^{-1})	Importance value index (IVI)	Species diversity (H)	Concentration of dominance
Chorgalia Sal oldgrowth forest	*Shorea robusta*	194.0	51.2	173.8		
	Mallotus philippensis	106.0	3.4	61.5	1.79	0.34
	Others	93.0	2.3	64.7		
	Total	393.0	56.9	300.0		
Chorgalia Sal coppice forest	*Shorea robusta*	488.0	33.1	198.7		
	Others	238.0	8.8	101.3	2.01	0.48
	Total	726.0	39.9	300.0		
Kalona pine-mixed broadleaf forest	*Pinus roxburghii*	62.5	12.7	85.3		
	Quercus leucotrichophora	29.8	3.5	38.8		
	Quercus glauca	17.3	1.4	15.0	3.86	0.09
	Pyrus pashia	7.8	0.5	9.4		
	Others	197.3	6.2	151.5		
	Total	314.7	24.3	300.0		
Baldiyakhan pine forest	*Pinus roxburghii*	575.0	33.3	246.9		
	Others	82.0	2.6	53.1	0.72	0.77
	Total	657.0	35.9	300.0		
Ranikhet mixed-oak-pine forest	*Quercus leucotrichophora*	433.0	19.1	134.8		
	Pinus roxburghii	67.0	12.1	54.8	1.70	0.42
	Cedrus deodara	33.0	3.0	22.3		
	Others	250.0	6.3	88.1		
	Total	783.0	40.5	300.0		
Kilbury Rianj-dominated mixed oak forest	*Quercus lanuginosa*	629.0	42.2	179.2		
	Quercus floribunda	257.0	13.4	80.5	1.35	0.47
	Quercus leucotrichophora	21.0	0.6	9.6		
	Others	86.0	3.5	30.7		
	Total	993.0	59.7	300.0		
Kilbury Tilonj-dominated mixed oak forest	*Quercus floribunda*	85.0	54.1	194.3		
	Quercus leucotrichophora	93.0	7.3	39.8	1.23	0.62
	Quercus lanuginosa	100.0	8.6	39.1		
	Others	64.0	2.1	26.8		
	Total	342.0	72.1	300.0		

The maximum fall of reproductive biomass was 51.2 g m^{-2} in the Rianj-dominated mixed oak forest at Kilbury, followed by the mixed oak-pine forest at Ranikhet (57.7 g m^{-2}), the Baldiyakhan pine forest (43.3 g m^{-2}), Chorgalia sal old growth forest (27.4 g m^{-2}), Chorgalia sal coppice forest (21.8 g m^{-2}), the Tilonj-dominated mixed oak forest at Kilbury (21.2 g m^{-2}) and the pine-mixed broadleaf forest at Kalona (3.6 g m^{-2}). These values were 11.1, 9.3, 5.1, 3.3, 3.2, 3.4 and 1.0% of the total litter production on the respective sites.

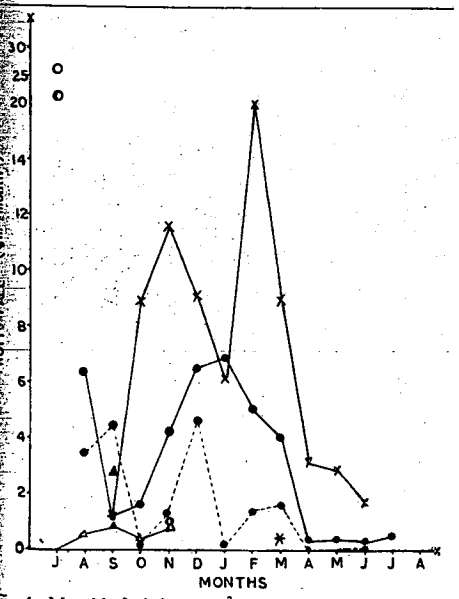

Fig. 1. Monthly fruit fall (g m^{-2}) pattern in *Shorea robusta* in sal oldgrowth (o) and sal coppice (●) forests; *Quercus glauca* + *Quercus leucotrichophora* (⊙) and *Pyrus pashia* (△); in pine mixed-broadleaf forest; *Pinus roxburghii* (▲) in pine forest; *Q. leucotri chophora* (•) and *Cedrus deodara* (*) in mixed oak-pine forest; *Quercus lanuginosa* + *Quercus floribunda* + *Quercus leucotrichophora* (×) in Rianj-dominated mixed oak forest; and *Quercus floribunda* + *Quercus leucotrichophora* + *Quercus lanuginosa* (•-•); in Tilonj-dominated mixed oak forest.

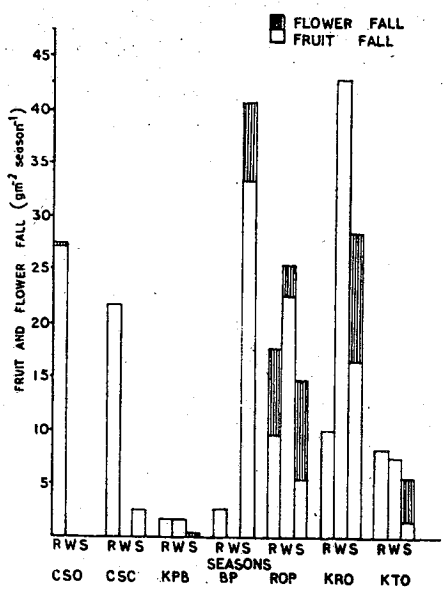

Fig. 2. Seasonal pattern in flower and fruit restitution in different forests, CSO (Chorgalia, sal oldgrowth forest), CSC (Chorgalia, sal coppice forest), KPB (Kalona, pine mixed-broadleaf forest), BP (Baldiyakhan pine forest), ROP (Ranikhet, mixed oak-pine forest), KRO (Kilbury, Rianj-dominated mixed oak forest), and KTO (Kilbury, Tilonj-dominated mixed oak forest). R = Rainy season, W = Winter season and S = Summer season.

The highest fruit output was recorded in the Rianj-dominated mixed-oak forest at Kilbury (69.2 g m^{-2}) followed by the mixed oak-pine forest at Ranikhet (37.5 g m^{-2}). The flower fall was highest for the mixed oak-pine forest at Ranikhet (20.3 g m^{-2}) where *Q. leucotrichophora*, the dominant species, contributed 8.8 g m^{-2} and *C. deodara* and *P. roxburghii* 11.0 and 0.5 g m^{-2}, respectively. The lowest flower fall was 0.1 g m^{-2}), recorded for *M. philippensis* in Chorgalia sal oldgrowth forest.

DISCUSSION

The total restitution of reproductive biomass in the sal forest was less than the values (98.8 - 366.8 g m^{-2}) reported by Narayan Rao (1970), Anon. (1971), and Verma & Sharma (1978) for certain sal forests, but

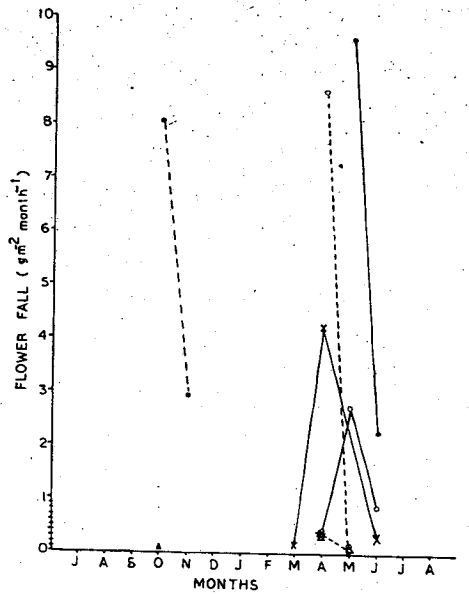

Fig. 3. Monthly flower fall in *Mallotus philippensis* (▲) in sal oldgrowth forest; *Quercus glauca* + *Quercus leucotrichophora* (*) in pine-mixed broadleaf forest; *Pinus roxburghii* (×) in pine forest; *Quercus leucotrichophora* (o—o), *Cedrus deodara* (•---•) and *Pinus roxburghii* (Δ---Δ) in mixed oak-pine forest; *Quercus lanuginosa* + *Quercus floribunda* + *Quercus leucotrichophora* (•) in Rianj-dominated mixed oak forest and. *Quercus floribunda* + *Quercus leucotrichophora* + *Quercus lanuginosa* (°) in Tilonj-dominated mixed oak forest.

higher than the values (0.4 to 5.1 g m^{-2}) reported by Ray Chowdhary (1970) for West Bengal and Sharma (1981) for Dehra Dun sal forests. These differences may be due to stocking density, year to year variability and climate. The reproductive fall in the Kalona pine-mixed broadleaf forest was lowest in the present study and was also less than the value 7.7 g m^{-2} reported by Lawson & Cottam (1971) for an oak-Wisconsin forest. This value is very low compared to values (32.0 to 105.0 g m^{-2}) reported by Safarov & Djhalilov (De Angelis *et al.*, 1980) and Alvera (De Angelis *et al.*, 1980) for subtropical oak (*Quercetum nudum*) forest in USSR and for pine-Holley forest in Spain. The reproductive fall for the Baldiyakhan pine forest is within the range (38.2 to 48.0 g m^{-2}) reported for coniferous forests by Lemee (De Angelis *et al.*, 1980) and Gordon (De Angelis *et al.*, 1980) but less than the value (105.0 g m^{-2}) reported by Alvera (De Angelis *et al.*, 1980) for a pine-Holly forest from Spain. The value for the Ranikhet mixed oak-pine forest is within the range (51.0 to 59.6 g m^{-2}) reported by Rapp (1971), Malaisse *et al.* (1972) and Andersson (De Angelis *et al.*, 1980) for mediterranean evergreen oak forest (France), Miombo-Woodland (Zaire) and for an oak-Hazel forest (Sweden), respectively. The reproductive fall in Kilbury Rianj-dominated mixed oak forest is within the range (70.6–79.0 g m^{-2}) reported by Van der Drift (1974) and Nihlgard & Lindgren (1977) for an oak forest (Netherlands) and for a beech-Mercurialis-type (Sweden) forest. The reproductive fall for the Kilbury Tilonj-dominated mixed oak forest lies within the range (20.7–23.0 g m^{-2}) as reported by Holm & Jensen (De Angelis *et al.*, 1980), Satchell (1971), Whittaker & Woodwell (De Angelis *et al.*, 1980) and Hyttenborn (De Angelis *et al.*, 1980) for temperate deciduous-beech (Denmark), mixed deciduous forest (United Kingdom), oak-pine forest (USA) and deciduous *Quercus-Betula-Corylus* forest (Sweden), respectively.

Fruit predation by wild animals, birds, and insects is a major cause of loss of seeds and fruits from plants, litter and soil (Salisbury, 1942; Janzen, 1970, 1971). Saxena (1979), Tewari & Singh (1981) and Upreti (1982) conclude that the biotic pressure (specialized or generalized) is very high in the Kumaun Himalaya, mostly in oak, oak-pine and pine forest. In the present study sites, important fruit, flower and seed predators are: *Presbytis entellus* (langur), *Macaca mulatta mulatta* (monkey), *Solenarctos tibetanus tibetanus* (black bear), *Rattus rattus rattus* (rat), *Hystrix indica indica* (Indian porcupine), *Chlorophorus strobilicola*, *Blastobasis transcripta*, *Dioryctria abeetelia*, *Calandra* sp., *Eucosma dryocarpa*, *Dioronognathus nubulosus* and *Endrmonis disporma*. The predation is evidently much higher in the sal and pine-mixed broadleaf forest.

Flowering and fruiting is the most dynamic process of forest systems which tend to be rather more variable in its timing than other seasonal changes. The ecological interpretation of the timing of flowering is complex. From the present study it is evident that in deciduous tree species this is related to the period when the branches are more or less leafless or with leaves only partly grown and in evergreen species (*Q. lanuginosa*, *Q. floribunda*, *Q leucotrichophora*, *Q. glauca*, *P. roxburghii* and *C. deodara*), when the foliage mass is thin. This observation is in conformity with Janzen (1967), Croat (1969), Daubenmire (1972) and Frankie *et al.* (1974). According to Richards (1952), Snow (1966), Janzen (1967) and Smythe (1970) this pattern maximizes vegetative competitive ability and the use of pollinators and dispersal agents. Further, most of the overstorey tree species, except for *C. deodara*, reproduce before the onset of winter, marked by a time of environmental stress. Stebbins (1957) and Wareing (1958) conclude that this offers several ecological advantages to secure adaptation. Gallegos (1981) opined that flowering and fruiting is related to elevation, latitude and topographic features. In this study, the correlation between reproductive output and altitude was not significant (r = 0.46). Relation of reproducting output with total litter fall (r=0.613), and total tree density (r=0.616) tended to be positive but non-significant statistically. However, the relationship of reproductive fall with density of tree species whose reproductive organs were captured in traps was significant (r=0.866, P<0.05). The total fall of reproductive biomass tended to be inversely related with Shannon-Wiener information function (r = −0.584).

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REFERENCES

ANON. (1971). Sal seed and its utilization. *Regional Research Laboratory, Bhubaneswar, Technical note No. 1-71*, p. 2.

CROAT, T.B. (1969). Seasonal flowering behaviour in Central Panama. *Annals of the Missouri Botanical Garden* **56**, 295-307.

CURTIS, J.T. & MCINTOSH, R.P. (1951). An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecology* **32**, 476-496.

DAUBENMIRE, R. (1972). Phenology and other characteristics of tropical semi-deciduous forest in north western Costa Rica. *Journal of Ecology* **60**, 147-170.

DEANGELIS, D.L., GARDNER, R.H. & SHUGART, H.H. (1980). Productivity of forest ecosystems studied during the IBP: the Woodlands data set. In *Dynamic Properties of Forest Ecosystems* (ed. D.E. Reichle) pp. 567-672. Cambridge University Press, Malta.

FRANKIE, G.W., BARKER, H.G. & OPLER, P.A. (1974). Comparative phenological studies in tropical wet and dry forests in the lowlands of Costa Rica. *Journal of Ecology* **62**, 881-919.

GALLEGOS, C.M. (1981). Flowering and seed production of *Pinus roxburghii* var. *honduransis*. (Preliminary results of a worldwide survey). *Forest Genetic Resource Information No. 10 FAO*. pp. 17-22.

GORDON, A.G. (1976). *Canadian Journal of Botany*. 781-813. Quoted by DeAngelis, Gardner & Shugart (1980).

JANZEN, D.H. (1967). Synchronization of sexual reproduction of trees within the dry season in central America. *Evolution* **21**, 620-637.

JANZEN, D.H. (1970). Herbivores and the number of tree species in tropical forests. *American Naturalist* **104**, 501-528.

JANZEN, D.H. (1971). Seed predation by animals. *Annual Review of Ecological System* **2**, 465-492.

LAWSON, G.W. & COTTAM, G. (1971). *Eastern Deciduous Forest Biome, Memo*. 71-51.

MALAISSE, F.J., ALEXANDRA, J., FRESON, R., GOFFINET, G. & MALAISSE-MOUSSET, G. (1972). The Miombo ecosystem: A preliminary study. In *Tropical Ecology* (eds. F. Golley & B. Golley) pp. 363-405. Institute of Ecology Athens, *U.S.A.*

MUELLER-DOMBOIS, D. & ELLENBERG, H. (1974). *Aims and Methods of Vegetation Ecology*. John Wiley, New York. 547 pp.

NARAYAN RAO, M. (1970). Nutritive value of (i) Sal (*Shorea robusta*) butter fat and (ii) residual sal meal – present status of the problem. In *Meeting of Sal Seed Fat and By-products, Hyderabad*. pp. 25-27.

NIHLGARD, B. & LINDGREN, L. (1977). Plant biomass primary productivity and bioelements of three mature beech forests in South Sweden. *Oikos* **28**, 95-104.

PANDEY, UMA & SINGH, J.S. (1981). A quantitative study of the forest floor, litter fall and nutrient return in an oak-conifer forest in Himalaya. I. Composition and dynamics of forest floor. *Oecologia Generalis (Acta ecologica)* **2**, 49-61.

RAPP, M. (1971). Cycle de la matiere organique et des elements mineraux dans quelques ecosystems mediterarrunnees. *C.N.R.S.* **40**, 19-184 (F).

RICHARDS, P.W. (1952). *The Tropical Rain Forest*. Cambridge, England. 450 pp.

RAY CHOWDHARY, K.C. (1970). Prospects of collection of sal seeds in West Bengal. In *Meeting of Sal seed Fat and By-products, Hyderabad*, pp. 14-18.

SALISBURY, E.J. (1942). *The Reproductive Capacity of Plants*. Bell Publishers, London.

SATCHELL, J.E. (1971). In *Productivity of the Forest Ecosystems of the World*. (ed. P. Duvigneaud), UNESCO Press.

SAXENA, A.K. (1979). *Ecology of vegetation complex of North-western catchment of river Gola*. Ph.D. Thesis, Kumaun University, Naini Tal.

SAXENA, A.K. & SINGH, J.S. (1982). A phytosociological analysis of woody species in forest communities of a part of Kumaun Himalaya. *Vegetatio* **50**, 3-32.

SHANNON, C.I. & WIENER, Q.W. (1967). *The Mathematical Theory of Communication*. University of Illinois Press, Urbana.

SHARMA, B.K. (1981). Further studies on production in sal (*Shorea robusta* Gaertn.) crops in Dehra Dun district (U.P.). *Indian Forester* **107**, 505-509.

SMYTHE, N. (1970). Relationships between fruiting seasons and seed dispersal methods in a Neotropical forest. *American Naturalist* **104**, 25-35.

SNOW, D.W. (1966). A possible selective factor in the evolution of fruiting seasons in a tropical forest. *Oikos* **15**, 274-181.

STEBBINS, G.L. (1957). *Variation and Evolution in Plants*. Columbia University Press, New York, 643 pp.

TEWARI, J.C. & SINGH, S.P. (1981). Vegetation analysis of forest lying in transitional zone between lower and upper Himalayan moist temperate forest. In *Proceeding of the National Seminar on the Vegetational Wealth of Himalaya*. Garhwal University, Srinagar, 104-119.

UPRETI, N. (1982). *A study of phytosociology and state of regeneration of oak forest at Naini Tal*. Ph.D. Thesis, Kumaun University, Naini Tal.

VALDIYA, K.S. (1980). Stratographic scheme of the sedimentary units of the Kumaun Lesser Himalaya. In *Stratigraphy and Correlations of the Lesser Himalayan Formations*. (ed. K.S. Valdiya & S.B. Bhatia) pp. 7-48. Hindustan Publication Corporation, Delhi.

VAN DER DRIFT, J. (1974). *Final report 1966-71 of the Netherlands contribution to the IBP*. North Holland

Publication Company, Amsterdam, pp. 26-32.

VERMA, V.P.S. & SHARMA, B.K. (1978). Studies on production and collection of Sal (*Shorea robusta* Gaertn.) seeds. *Indian Forester* **104**, 414-420.

WAREING, P.E. (1958). Reproductive development in *Pi sylvestris*. In *The physiology of Forest Tre* (ed. K.V. Thimann) pp. 643-654. Ronald Press, New Yo

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