Indian Journal of Ecology (2022) 49(4): 1271-1275
DOI: https://doi.org/10.55362/IJE/2022/3656

Manuscript Number: 3656
NAAS Rating: 5.79

Effect of Altitude on Seed Dispersal and Seedling Establishment of *Shorea robusta* Roth. in Garhwal Himalaya

Radheshyam Junjariya and A.K. Negi
Department of Forestry and Natural Resources, H.N.B. Garhwal University (A Central)
Srinagar, Garhwal-246 174, India,
E-mail: radheyraj@hotmail.com

Abstract: *Shorea robusta* is the most dominated species of tropical forest in India. The seed dispersal and regeneration status were studied during the period June 2019 to May 2021. Seed traps were placed for seed dispersal. Traps were round shape baskets with 60 cm open face diameter and place 1m above ground height. For the study of regeneration, 1*1 quadrates were laid down next to each trap. Total 30 traps and 30 quadrates were placed for each study site. The middle elevation (900m) shows better results in comparison to a lower elevation (600m) for seed dispersal and seed germination. The seed germination and seed survival were also compared as inside forest and outside *Shorea robusta* forest for both elevations. Seed germination is similar inside the forest for both elevation and outside the forest for elevation but there is a significant difference between inside forest and outside the forest for both elevations. The middle elevation shows better results for germination and survival of seeds of *Shorea robusta.*

Keywords: *Shorea robusta*, Seed dispersal, Seed trap, Seed germination, Inside forest, Outside forest

Indian Himalayan Region (IHR) sustains a variety of vegetation in the form of different forests. The part of IHR located within the state of Uttarakhand, known as Garhwal Himalaya, harbours forest types at different elevations i.e., extending from foothill to middle Himalaya. Among these one such type is the Sal forests dominated by the Sal tree (*Shorea robusta* Roth.) also, the major forest types in South Asia. Sal is a tropical tree species belonging to the family Dipterocarpaceae having well documented three sub-families, 17 genera and 511 species (Surabhi et al 2017) forming open to dense forests. The species is naturally found in Bhutan, Bangladesh, Nepal and India between 75º and 95º E longitude and 20º to 32º N latitude (Gautam and Devoe 2006, Sapkota, 2009). In India, Sal Forest is cosmopolitan in tropical regions covering 13.3% of the entire forest area within the country. The distribution extends up to the Assam valley (including Meghalaya and Tripura) in the east to the foothills of north-west Bengal, Uttar Pradesh, Uttarakhand, and Kangra region of Himachal Pradesh.

Seed dispersal is wind-driven. The recalcitrant seeds and short period of areal viability of *Shorea robusta* make the species of great interest to the forest researchers and plantation managers (Phartyal et al 2002 and Pattanaik et al 2015). Natural regeneration, the inherent ability of the species to breed itself is a direct indicator of the health of a forest ecosystem. Though, many factors reported to affect the process of natural regeneration (Doroski et al 2018) includes climate (humidity, temperature, light intensity, a span of light-receiving hours, precipitation and wind). soil (depth, aeration, moisture level, nutrients and erosion), seed (sensitivity, output and dispersal) and biotic conditions (wildlife, forest fire, and over-grazing), etc. seed viability losses leads by the long transportation period from collection site to nurseries (Dumroese et al 2016). The studies on the seed germination and seedling survival of Sal in a natural condition are well documented (Pattanaik and Dash 2015, Gautam and Devoe 2006). However, in the state of Uttarakhand prominent lack of such research for the study of forest covers where the Sal Forest cover especially in the Lansdowne Forest Division (LFD) region has been observed to be reduced. This forest division registered and accredited as Conservation Assured Tiger Standards (CATS) site in India dated 25 May 2017. CATS is a programme that satisfy a group of standards and criteria to promotes protected areas to assure effective and continuous tiger conservation, formed by conservation managers and international professionals. This region facilitates the movement of wild animals such as tiger and elephant between Corbett Tiger Reserve and Rajaji Tiger Reserve (Williams 2002, Harihar et al 2009). Thus, the region is ecologically important. The declining distribution of economically and ecologically important Sal forests underpins the importance of the present piece of work to investigate the seed production, seed dispersal and seed germination of this dominant species in natural conditions at different altitudes in the LFD.

MATERIAL AND METHODS

Study area: Lansdowne Forest Division located between Shivalik range and Lower Himalayan ecoregion and Terai Arc Landscape of India. It is situated between 29° 22' 12" - 30° 1' 12"N and 78° 11' 24" - 78° 25' 48"E in the district Pauri Garhwal. The study area includes Sal forests, grasslands, mixed forests (characterized by *Mallotus philippensis, Terminalia tomentosa, Anogeisus latifolia and Diospyros montana* etc), and pine forests and elevation range between 300-1300 m. There are five ranges (Kotdi, Dugadda, Lansdowne, Kotdwar, and Laldhang) in this division with 433 km^2 total geographical area. For the present study, the falling station was selected in different ranges according to elevation:

1. The sampling station first Aamsaur Forest Area falls under the Dugadda Forest Range. This station is located at elevation 600 masl and 29° 46' 52"N and 78° 34' 54"E. (Lower Elevation).
2. The second sampling station Fatehpur Forest Area also falls under Dugadda Forest Range. This station is situated at the altitude of 900 masl and 29° 49' 46"N and 78° 36' 56"E. (Middle Elevation).
3. The third sampling station Batkot Forest Area comes under the Lansdowne Forest Range. This station is situated at the altitude of 1200 masl and 29° 51' 45"N and 78° 38' 03"E. (Higher Elevation).

Methodology

Seed dispersal: Seed traps were placed to sample seed rain inside and outside the forest patches. The circular baskets with a 60 cm radius, made up of bamboo and lined with plastic sheets were used as seed traps. Three stakes (1.5-m high) were used to raise the seed traps above the ground to avoid predation by rodents. The traps height differs for undulate ground surface and steeply area. Traps were arranged inside the forest and within the matrix outside the forest. In the matrix outside the forest, the arrangement was along transects with side water bodies and drainage lines (total of 30 traps were set inside and outside the forest. The coordinates (x, y) of every trap and potential seed source tree were established. The traps were installed in June 2019 and

Table 1. GPS Location of laid quadrats in all three study sites

Quadrat N.	Aamsaur		Fatehpur		Batkot	
	Inside Forest	Outside Forest	Inside Forest	Outside Forest	Inside Forest	Outside Forest
1.	N 29° 46' 52.35" E 78° 34' 55.66"	N 29° 46' 54.82" E 78° 34' 56.66"	N 29° 49' 46.45" E 78° 36' 56.27"	N 29° 49' 49.46" E 78° 36' 56.80"	N 29° 51' 41.97" E 78° 38' 7.97"	N 29° 51' 40.26" E 78° 38' 7.82"
2.	N 29° 46' 52.21" E 78° 34' 55.21"	N 29° 46' 55.15" E 78° 34' 56.28"	N 29° 49' 46.38" E 78° 36' 55.86"	N 29° 49' 49.57" E 78° 36' 56.40"	N 29° 51' 41.99" E 78° 38' 8.62"	N 29° 51' 40.05" E 78° 38' 7.82"
3.	N 29° 46' 52.19" E 78° 34' 54.69"	N 29° 46' 55.38" E 78° 34' 55.82"	N 29° 49' 46.31" E 78° 36' 55.49"	N 29° 49' 49.62" E 78° 36' 56.09"	N 29° 51' 42.03" E 78° 38' 8.81"	N 29° 51' 39.82" E 78° 38' 7.89"
4.	N 29° 46' 52.11" E 78° 34' 54.34"	N 29° 46' 55.71" E 78° 34' 54.98"	N 29° 49' 46.28" E 78° 36' 55.14"	N 29° 49' 49.81" E 78° 36' 55.79"	N 29° 51' 42.01" E 78° 38' 8.32"	N 29° 51' 39.63" E 78° 38' 8.01"
5.	N 29° 46' 52.08" E 78° 34' 53.89"	N 29° 46' 55.58" E 78° 34' 54.60"	N 29° 49' 46.39" E 78° 36' 54.80"	N 29° 49' 50.07" E 78° 36' 55.59"	N 29° 51' 41.97" E 78° 38' 9.01"	N 29° 51' 39.51" E 78° 38' 7.82"
6.	N 29° 46' 52.66" E 78° 34' 55.91"	N 29° 46' 55.83" E 78° 34' 54.27"	N 29° 49' 46.83" E 78° 36' 56.33"	N 29° 49' 50.37" E 78° 36' 55.56"	N 29° 51' 41.79" E 78° 38' 7.96"	N 29° 51' 39.32" E 78° 38' 8.08"
7.	N 29° 46' 52.57" E 78° 34' 55.33"	N 29° 46' 56.20" E 78° 34' 54.01"	N 29° 49' 46.71" E 78° 36' 55.85"	N 29° 49' 50.61" E 78° 36' 55.48"	N 29° 51' 41.83" E 78° 38' 8.17"	N 29° 51' 39.08" E 78° 38' 7.92"
8.	N 29° 46' 52.52" E 78° 34' 54.84"	N 29° 46' 55.59" E 78° 34' 55.45"	N 29° 49' 46.59" E 78° 36' 55.62"	N 29° 49' 50.73" E 78° 36' 55.35"	N 29° 51' 41.86" E 78° 38' 8.35"	N 29° 51' 38.88" E 78° 38' 8.06"
9.	N 29° 46' 52.35" E 78° 34' 54.34"	N 29° 46' 56.44" E 78° 34' 53.83"	N 29° 49' 46.52" E 78° 36' 55.25"	N 29° 49' 50.88" E 78° 36' 55.47"	N 29° 51' 41.87" E 78° 38' 8.60"	N 29° 51' 38.77" E 78° 38' 8.24"
10.	N 29° 46' 52.30" E 78° 34' 53.82"	N 29° 46' 56.52" E 78° 34' 53.49"	N 29° 49' 46.61" E 78° 36' 54.94"	N 29° 49' 50.98" E 78° 36' 55.17"	N 29° 51' 41.79" E 78° 38' 8.81"	N 29° 51' 38.64" E 78° 38' 8.12"
11.	N 29° 46' 53.03" E 78° 34' 55.86"	N 29° 46' 56.71" E 78° 34' 53.19"	N 29° 49' 47.09" E 78° 36' 56.58"	N 29° 49' 51.18" E 78° 36' 55.02"	N 29° 51' 41.61" E 78° 38' 7.98"	N 29° 51' 38.49" E 78° 38' 8.23"
12.	N 29° 46' 52.90" E 78° 34' 55.26"	N 29° 46' 57.03" E 78° 34' 52.86"	N 29° 49' 47.01" E 78° 36' 56.13"	N 29° 49' 51.24" E 78° 36' 54.68"	N 29° 51' 41.71" E 78° 38' 8.25"	N 29° 51' 38.35" E 78° 38' 8.19"
13.	N 29° 46' 52.87 E 78° 34' 54.77"	N 29° 46' 57.21" E 78° 34' 52.52"	N 29° 49' 46.93" E 78° 36' 55.68"	N 29° 49' 51.20" E 78° 36' 54.36"	N 29° 51' 41.71" E 78° 38' 8.49"	N 29° 51' 38.26" E 78° 38' 8.11"
14.	N 29° 46' 52.91" E 78° 34' 54.29"	N 29° 46' 57.37" E 78° 34' 52.10"	N 29° 49' 46.87" E 78° 36' 55.26"	N 29° 49' 51.26" E 78° 36' 54.06"	N 29° 51' 41.64" E 78° 38' 8.69"	N 29° 51' 38.06" E 78° 38' 7.91"
15.	N 29° 46' 52.72" E 78° 34' 53.74"	N 29° 46' 57.60" E 78° 34' 51.76"	N 29° 49' 46.95" E 78° 36' 54.88"	N 29° 49' 51.23" E 78° 36' 53.72"	N 29° 51' 41.58" E 78° 38' 8.91"	N 29° 51' 37.95" E 78° 38' 7.82"

were monitored during the fruit setting period up to September 2019. Seeds were collected every week, counted at the spot. This routine was repeated until no more seeds were retrieved from the traps (Abiyu et al 2016).

Regeneration study: The next to every trap, 1 m^2 (1 m × 1 m) plots were prepared, where seeds were marked with toothpicks and monitored for emerging seedlings. The established plants and germinates are rare in the studied habitats, tree establishment was observed in areas with freshly exposed soil by human activity. To validate seed dispersal kernels with plant distribution, a further set of 15 plots (2 m × 2 m) were laid with additional transects running from seed sources into the open habitats (Abiyu et al 2016).

Statistical analysis: Descriptive statistics were used to visualize the number of seeds reaching different traps located in the various habitats at different altitudes. In the 1 m × 1m plots along the transects, an independent sample T-test with equal sample sizes was performed for the significant differences in the emergence of seeds between these habitats. The Minitab-18 statistical software were used to present the box plot.

RESULTS AND DISCUSSION

Seed dispersal: The middle elevation (Fatehpur Forest Area) shows the maximum number of seeds dispersed inside the forest as compared to the lower elevation (Aamsaur Forest Area). The average number of dispersed seeds outside the forest was 3.73 seeds in quadrate and 1.33 seeds in seed-traps for middle elevation (Fatehpur Forest Area) and 2.93 seeds in quadrate and 0.73 seeds in seed-traps for the lower elevation (Aamsaur Forest Area). The middle elevations (Fatehpur Forest Area) recorded an average number of dispersed seeds inside the forest being 27.4 seeds in quadrate and 11.46 seeds in seed-traps. The lower elevation (Aamsaur Forest Area) recorded 26.6 seeds in quadrate and 10.66 seeds in seed-traps. The dispersal of seeds was significantly different for the middle elevation and lower elevation and, into seeds in seed-traps and quadrate (Fig. 1). The variation in climatic conditions has a significant impact on seed production of Shorea robusta (Kumar and Chopra, 2018). Spring flushing, semi-evergreen *Shorea robusta* started out flowering with the onset of leaf fall in winter. Its flowering (January–April) coincided with the leaf transitional state (leaf fall, leaf initiation), and fruit formation and leaf flushing both were supported at the same time (Singh and Kushwaha 2006). In tropical forest, flowering is brought on by means of elements consisting of increased day period, solar intensity and temperature (Boulter et al 2006, Borah and Devi 2014). Based on the finding on phenology it may be stated that enough moisture content and temperature during favorable growth season are key determinants for growth and development in *S. robusta* (Kumar and Chopra 2018).

Distance of seed dispersal: The maximum distance (390m) was recorded for the middle elevation (Fatehpur Forest Area) outside the forest as compared to the (330m) lower elevation (Aamsaur Forest Area). The trend line shows the downward movement with the distance of the number of seeds dispersed. The seed dispersal distance is significantly different for the middle elevation and lower elevation (Fig. 2). The proximity of regeneration sites to the seed source has a significant impact on regeneration success (Holl 2008). For animal disseminated species Clark et al (2005) found up to 473 m dispersal distances. It has been found that the animal-dispersed tree species seeds have a longer dispersal distance than wind-dispersed tree species seeds (Montoya et al 2008, Nazareno et al 2021).

Germination of seeds: The germination percent of seeds of *Shorea robusta* was recorded outside the forest for the

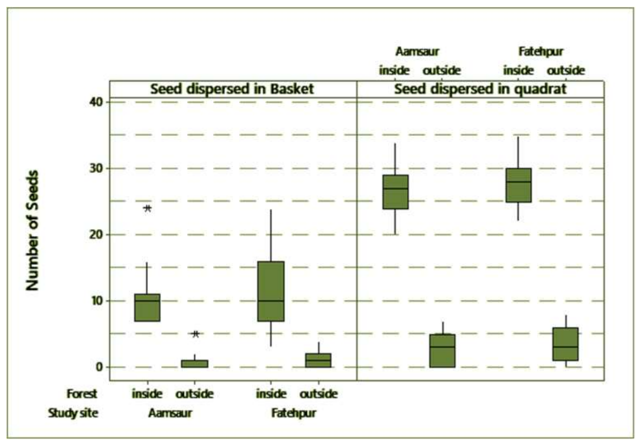

Fig. 1. Box plot for both study sites with comparative seed dispersal between inside and outside the forest and in basket and quadrates

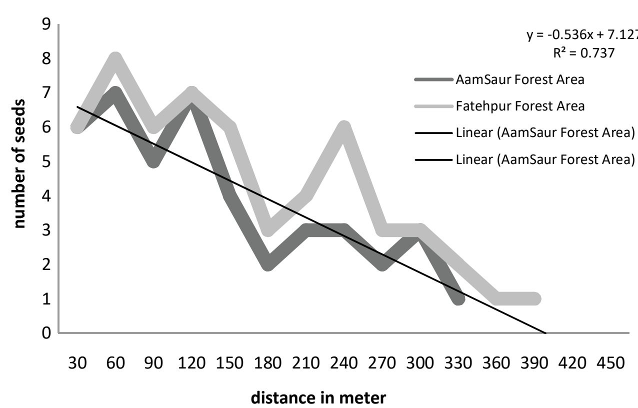

Fig. 2. Seed dispersal distance from the forest area for both forest sites

Aamsaur forest area was 40.41% and for the Fatehpur, Forest Area was 45.87%. The middle elevation (Fatehpur Forest Area) shows the highest percent of germination 73.09% and 71.8% in the lower elevation (Aamsaur Forest Area) inside the forest. The germination of *Shorea robusta* in both sites is found significantly different at 1%. The numbers of seeds produced varied between both elevations (Fig. 3). Seed viability of Sal last till a weak. The occurrence of rain within a week of seed fall take germination rate upto 90 %. Delay in rain can reduce the germination of seeds. The germination pattern of different plant communities is changed with the change in the elevation (Devi et al 2019). The range of seedlings was recorded from 38.89 to 67.35% (Mittal et.al 2020). Germination of seeds is also led by the maturity level of seeds (Phartyal et al 2002). Regeneration status was very poor in natural forest (Ganguli and Joshi, 2020). Sal has a tendency of germination in mass of seedlings in favourable conditions (light, soil, moisture with true drainage) in even aged vegetation, which can be highly natural (Saatkamp 2014). The 5000 seedlings per hectare and (Behera et al 2021) and 50000-100000 seedlings per hectare Sal forests beneath uniform Shelterwood system found after regeneration felling (Awasthi et al 2015, Gaire and Ghimire 2019).

Survival of seedling: The survival of seedlings outside the forest for the Aamsaur Forest Area was 6.0% and for the Fatehpur Forest Area 9.33%. The lower elevation (Aamsaur Forest Area) shows the percent of survival was 32.47% inside the forest and 39.14%in middle elevation (Fatehpur Forest Area). The survival of *Shorea robusta* in both sites was significantly different. The survival percent for the seedling of *Shorea robusta* is deficient outside the forest (Fig. 4) and Sal ranges between 3.01 to 7.59 (Mittal et al 2020). The survival of seedlings was about 2% in natural condition (Awasthi et al 2015). Survival of seedlings was good as high number of

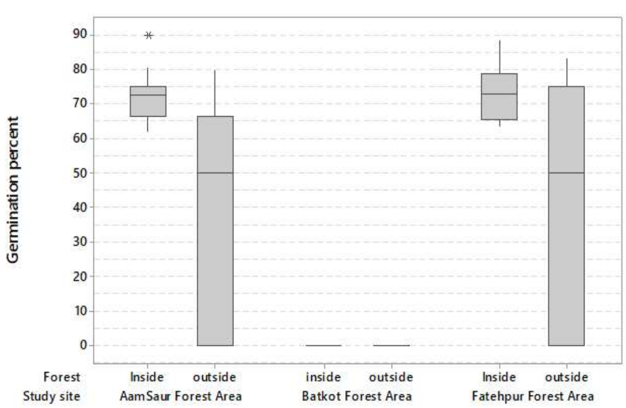

Fig. 3. Box plot for both study sites with comparative germination percent between inside and outside the forest

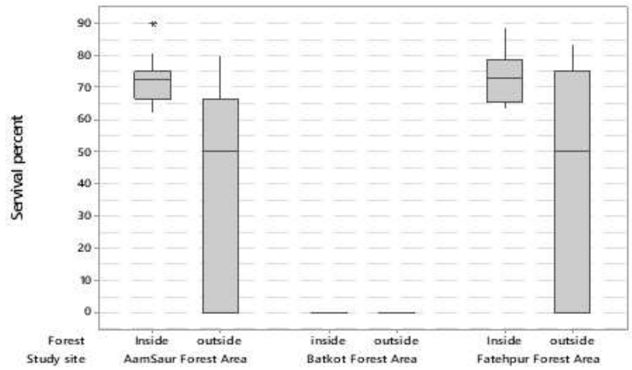

Fig. 4. Box plot for both study sites with comparative survival percent between inside and outside the forest

saplings was recorded under natural conditions (Ganguli and Joshi 2020). The dispersed seed shows a different variance in survival at both elevations. Depending on the number of shelter trees, the die-back rate varied from 4 to 10 percent but among tallest 2000 seedling per hectare observed no die-back (Saatkamp 2014, Awasthi et al 2015, Gaire and Ghimire 2019). The seed size has also a potential impact of germination and survival of seedlings of Sal (Patnaik et al 2015). The change in elevation shows the change in survival pattern of different plant communities (Devi et al 2019). The regeneration patterns of tree species within the communities showed altitudinal shift changing pattern of community compositions. Seedling density increased by the open canopy areas which favored regeneration of some tree species and increasing the alimentation of species diversity (Sapkota 2009).

CONCLUSIONS

The seed amount and distance of seed dispersed is related to germination and survival of seed. The higher distance seed dispersed is not vulnerable for germination. The medium elevation is suitable for the establishment of germination and survival of the seedling.

REFERENCES

Abiyu A, Teketay D, Glatzel G and Gratzer G 2016. Seed production, seed dispersal and seedling establishment of two afromontane tree species in and around a church forest: implications for forest restoration. *Forest Ecosystems* **3:** 1-10.

Awasthi N, Bhandari SK and Khanal Y 2015. Does scientific forest management promote plant species diversity and regeneration in Sal (*Shorea robusta*) forest? A case study from Lumbini collaborative forest, Rupandehi, Nepal.*Banko Janakari* **25:** 1.

BeheraMC, Mohanty TL and Kar RK 2021. Species Diversity, Population Structure and Regeneration of Tree Species in Kuldiha Wildlife Sanctuary, Odisha, India. *Indian Journal of Ecology* **48**(5): 1343-1352.

Borah M and Devi A 2014. Phenology, growth and survival of *Vaticalanceaefolia* Bl.: A critically endangered tree species in moist tropical forest of Northeast India. *Tropical Plant Research* **1**(3): 1-12.

Boulter SL, Kitching RL and Howlett BG 2006. Family, visitors and the weather: Patterns of flowering in tropical rain forests of northern Australia. *Journal of Ecology* **94:** 369-382.

Clark C, Poulsen J, Bolker B, Connor E and Parker V 2005. Comparative seed shadows of bird-, monkey-, and wind-dispersed trees. *Ecology* **86**(10): 2684-2694.

Devi K, Samant SS, Puri S and Lal M 2019. Diversity, structure and regeneration pattern of tree communities in Kanawar Wildlife Sanctuary of Himachal Pradesh, North West Himalaya, India.*Indian Journal of Ecology* **46**(1): 94-103.

Doroski D, Felson A, Bradford M, Ashton M, Oldfield E, Hallett R and Kuebbing S 2018. Factors driving natural regeneration beneath a planted urban forest. *Urban Forestry & Urban Greening*. **29**. 10.1016/j.ufug.2017.11.019.

Dumroese RK, Haase DL, Wilkinson KM and Landis TD 2016. Collecting, Processing, and Treating Propagules for Seed and Vegetative Propagation in Nurseries. In: Pancel L., Köhl M. (eds) *Tropical Forestry Handbook.* Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-54601-3_93.

Gaire P and Ghimire P 2019. Comparison of regeneration and yield status between community forest and collaborative forest. *Grassroots Journal of Natural Resources* **2:** 1-2.

Ganguli S and Joshi H 2020. Regeneration status of some tree species in Garhjungle Sacred Forest, West Bengal, India. *Indian Journal of Ecology* **47**(4): 1033-1037.

Gautam KH and Devoe NN 2006. Ecological and anthropogenic niches of Sal (*Shorea robusta* Gaertn. f.) forest and prospects for multiple-product forest management: A review. *Forestry* **79**: 81-101.

Gautam KH and Devoe NN 2006. Ecological and anthropogenic niches of sal (*Shorea robusta* Gaertn. f.) forest and prospects for multiple-product forest management: A review, *Forestry: An International Journal of Forest Research* **79**(1): 81-101.

Godoy JA and Jordano P 2001. Seed dispersal by animals: Exact identification of source trees with endocarp DNA microsatellites. *Molecular Ecology* **10**(9): 2275-2283.

Harihar A, Pandav B and Goyal SP 2009. Responses of tiger (*Panthera tigris*) and their prey to removal of anthropogenic influences in Rajaji National Park, India. *European Journal of Wildlife Research.* **55:** 97-105.

Holl KD 2008. Are there benefits of bat roosts for tropical forest restoration? *Conservation Biology* **22**(5): 1090.

Kumar S and Chopra N 2018. Effect of Climate Change on Sal (*Shorea robusta* Gaertn. f.) Forest of Kumaun Himalaya. *American Journal of Environmental Sciences* **14**(4): 185-194.

Mittal A, Tewari A and Singh N 2020. Quantitative analysis and regeneration status of forest trees species in Kumaun Central Himalaya. *Indian Journal of Ecology* **47**(2): 507-513.

Montoya D, Zavala MA, Rodriguez MA and Purves D 2008. Animal Versus Wind Dispersal and the Robustness of Tree Species to Deforestation. *Science* **320**(5882): 1502-1504.

Nazareno AG, Knowles L, Christopher WD and Lohmann LG2021. By animal, water, or wind: Can dispersal mode predict genetic connectivity in riverine plant species? *Frontiers in Plant Science.* **12** 10.3389/fpls.2021.626405.

Pattanaik S and Dash A 2015. Seed germination and seedling survival percentage of *Shorea robusta* Gaertn.f. in buffer areas of Similipal Biosphere Reserve, Odisha, India. *Journal of Ecosystem & Ecography* **05**(01). 10.4172/2157-7625.1000153.

Pattanaik S, Dash A, Mishra RK, Nayak PK and Mohanty RC 2015. Seed Germination and Seedling Survival Percentage of *Shorea robusta* Gaertn. f. in Buffer Areas of Similipal Biosphere Reserve, Odisha, India. *Journal of Ecosystem Ecography* **4:** 153.

Phartyal S, Thapliyal RC, Nayal JS and Rawat M S2002. Late maturation changes in Sal (*Shorea robusta*) seed and their evaluation as indices for proper timing of seed collection. *Journal of Tropical Forest Science* **14**: 191-197.

Saatkamp A,Poschlod P and Venable L 2014. The Functional Role of Soil Seed Banks in Natural Communities. In Seeds - *The Ecology of Regeneration in Plant Communities* 3rd Edition. 3rd Edition, CABI, Wallingford.

Sapkotal P 2009. *Species diversity, regeneration and early growth of sal forests in Nepal: responses to inherent disturbance regimes*. Ph.D. Thesis, Swedish University of Agricultural Sciences, Alnarp.

Singh KP and Kushwaha CP 2006. Diversity of flowering and fruiting phenology of trees in a tropical deciduous forest in India. *Annals of Botany* **97:** 265-276.

Surabhi GK, Mohanty S, Meher R, Mukherjee A and Vemireddy L 2017. Assessment of genetic diversity in Shorea robusta: An economically important tropical tree species. *Journal of Applied Biology & Biotechnology* **5:** 110-117.

Williams AC 2002. *Elephants (Elephas maximus), their habitats in Rajaji–Corbett National Parks,* Northwest India. Ph.D. Thesis. Saurashtra University, Rajkot.

Received 22 February, 2022; Accepted 22 June, 2022