Indian Journal of Ecology (2022) 49(2): 559-563
DOI: https://doi.org/10.55362/IJE/2022/3561

Manuscript Number: 3561
NAAS Rating: 5.79

Seed Characteristics and Germination of *Quercus leucotrichophora* A. Camus Tree along the Elevation Gradient in Central Himalaya, India

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Abstract**:** *Quercus leucotrichophora* seeds were analyzed for color changes, seed size, weight, moisture content and germination along the elevation gradient. The seed germination was between 51.2 and 55.2 percent when the seed moisture content was between 35.9 and 38.8 percent .The change in mean weight of 100 seeds varied between 64.4 and 164.2 g at low elevation and the change in mean seed size was in between 31.2 and 222.6 mm^2, respectively. The change in mean weight of 100 seeds ranged between 74.7 and 63.3 g at middle elevation, and the change in mean seed size was in between 79.6 and 219.3 mm^2. Similarly at high elevation change in mean weight of 100 seeds was i between 63.6 - 90.2 and g and seed size was between 146.1 and 227.6 mm^2, respectively. The change in seed color was from dark green to dark brown, and the mean seed size was larger at the lower elevation than that of middle elevation, and the seed moisture content between 35.9 and 38.8 % during the first and second week of December considered to be a reliable indicator of maturity.

Keywords**:** Maturity, Moisture content, Germination, Himalaya, *Quercus leucotrichophora*

The Himalayan region is witnesses to various anthropogenic disturbances and vulnerable to climate change phenomenon, which degrading the ecosystems and make regeneration difficult. In the life cycle of forest trees, seed ripening is an important part. The variations in maturation time of seeds are a recommended way to study the effect of climatic variations on forest tree species (Bhatt and Ram 2015). Change in seed maturity period may influence the regeneration, development and hence impact stand composition and structure. Determining exact time of seed maturation is essential for the collection and regeneration of seeds. Physical attributed of seeds have been related to seed maturation in several species (Chauhan and Verma 1995; Tewari et al 2016). Climate change influences seedling dynamics of species by influencing seed germination and longevity of seeds in the soil banks. Young seedlings are more sensitive than adults to climatic irregularities. The oak forests of the region are broad leaved with approximately one year leaf life span and concentrated leaf drop during spring/summer. These forests have been placed under low to mid-montane hemi-sclerophyllous broadleaf forests. The genus *Quercus* includes has more than 400 species and is one of the most important tree species in temperate and subtropical plant communities is *Q. leucotrichohora* A. Camus (Banj Oak) is a major forest forming tree species in Uttarakhand Himalaya. The continued anthropogenic disturbances in this region create an early succession environment which makes the regeneration of the species difficult. Banj oak forest is an important component of Himalayan ecosystem from biodiversity conservation view-point; the local people generally relate oaks with water and soil conservation and in sustaining rural livelihoods (Purohit et al 2009). However, the species is under severe biotic pressure on account of its multiple uses as fodder, fuelwood, small timber, and charcoal. Due to its multiple uses, the pressure on these oak forests is relentless. Thus, the species is failing to regenerate in its natural environment for which climatic irregularities and anthropogenic pressure have been highlighted as the biggest culprits. Maturation time of seeds/acorns might shift due to global climate change phenomenon which further aggravating the regeneration issue. The aim of the present study was to determine the seed maturation period for conservation and management of *Q. leucotrichophora* species across an elevation transect and to observe the impact of climate change on seed maturation period.

MATERIAL AND METHODS

The study sites are located between 29°22'-29°24′ N Latitude and 79°25′-79°27′ E Longitude along an elevational transect of 1400 to 2200 m in Kumaun Himalaya, India. After a thorough survey, three elevations i.e., low elevation (1400-

1600 m), mid elevation (1700-1900 m) and high elevation (2000-2200 m) spread over 0.5 ha area each was selected during study period. The rocks of the study area are mainly sandstones, conglomerates, lime stones, quartzite, schist, granites and geniuses. The soil of the study area mainly sandy (40 to more than 60 % sand particles) with small amount of clay. The natural distribution of *Q. leucotrichophora* mainly between 1000-2200 m elevations and towards lower elevation associated with *Pinus roxburghii* Sarg. (chir Pine), a dominant tree species in the lower elevation of Uttarakhand Himalaya. *Q. leucotrichophora* grows either in pure stands and/or mixed with other broad-leaved and coniferous tree species. Among broad-leaved species, the main associates are *Myrica esculenta* Ham. Ex. D. Don, *Pyrus pashia* Buch. Ham, *Quercus glauca* Thunb at lower to middle elevations and *Lyonia ovalifolia* (Wall) Drude, *Quercus floribunda* Lindl, *Rhododendron arboreum* Smith, *Cedrus deodara* (Roxb.) G. Don at mid to high elevations. The mean tree diameter varies from 121.2 ± 1.9 cm at low elevation to 133.2 ± 3.2 cm at mid elevation while tree height ranged between 17.9 ± 0.8 m at high elevation to 23.1 ± 1.1 m at low elevations (Table 1).

Seeds collection and germination: Five phenotypically superior mature trees with well-developed crown of *Q. leucotrichophora* were randomly selected and marked for seed collection at each elevation. Height and CBH (at 1.37 m) of each selected tree were measured with Ravi Multimeter and measuring tapes, respectively. Collection of acorns (with involucre) of *Q. leucotrichophora* commenced from first week of October till the last week of December at all the elevations. The involucre (outer seed-based cap) was removed to determine the seed characteristics. The seeds were collected from the selected trees at each elevation and mixed to form a composite seed sample. For maturity indices seeds collection was made at an interval of 14 days till the seeds were available on marked trees. Five replicated of 25 seeds each, from the seed lot were used for determining various seed parameters. Seed size was taken as the product of length and width as mm^2 and measured with digital vernier caliper. Number of seeds per 100 gm was also determined. The seeds moisture content was expressed on the basis of fresh weight by drying at 103 ± 2°C for 16 ± 1 hr (Shah et al 2006, Tewari et al 2015) and then reweighted. Five replicates of 25 seeds each were used to determine germination percent. Seeds collected at each date were germinated on top of the seed germination paper in a dual door seed germinator at 25 ± 1°C. 2 mm radical emergence in seeds was the criteria followed for considering the seeds as germinated. Water was added as required during the experiment. Germination percent was calculated as the sum of total germinated seeds out of tested seeds for each elevation and each collection date within the test period. At the end of germination test, un-germinated seeds were percentage of seeds that had germinated at the end of the test was calculated following Paul (1972). The data were subjected to analysis of variance with a 95% confidence level using SPSS version 2007.

Table 1. Site and tree characteristics of *Quercus leucotrichophora* forests

Elevation (m)	Latitude and longitude	Tree characteristics	
		Diameter (cm)	Height (m)
Low (1400-1600)	29°20.994′ N 079°26.921′ E	121.2 ± 1.9	23.1 ± 1.1
Mid (1700-1900)	29°21.713′ N 079°27.580′ E	133.2 ± 3.2	20.1 ± 1.4
High (2000-2200)	29°23.350′ N 079°27.077′ E	126.6 ± 2.9	17.9 ± 0.8

RESULTS AND DISCUSSION

Seeds characteristics: The seed color changed from dark green at initial collection dates to dark brown at final collection dates during the study period (Table 2). The mean seed size increased from 131.2 mm^2 in first week of October to 228.4 mm^2 in third week of December at low elevation while at mid elevation, seed size increased from 79.6 mm^2 in first week of October to 239.3 mm^2 in second week of December. Similarly, at high elevation increased from 146.1 mm^2 in first week of October to 251.9 mm^2 in first week of December (Table 2). The mean weight of 100 seeds increased from 64.4 g in first week of October to 175.9 g in third week of December at low elevation, while at mid elevation, increased from 74.7 g in first week of October to 136.6 in third week of November. Similarly, at high elevation weight increased from 90.2 g in first week of October to 144.2 g in first week of December (Table 2). The mean number of seeds/100g decreased from 130.2 to 61.3 in fourth week of December at low elevation while at mid elevation, mean number decreased from 123.4 in first week of October to 56.9 in fourth week of December. Similarly, at high elevation, number of seeds decreased from 133.0 in first week of October to 30.5 in fourth week of December (Table 2). The correlation coefficient between seed size and moisture content and indicated that moisture content and indicated that moisture content was negatively correlated with seed size ($p < 0.01$) at low, mid, and high elevations (Fig. 1). The correlation coefficient was determined between moisture content and germination and indicated that germination was negatively correlated with moisture content at low and mid elevations (Fig. 2).

The percent moisture content of seeds decreased from

50.7 in first week of October to 31.1 in fourth week of December at low elevation while at mid elevation moisture content of seeds decreased from 57.8 in first week of October to 32.5 in fourth week of December. Similarly, at high elevation decreased from 61.6 (first week of October) to 27.2 per cent (fourth week of December) (Table 3). The germination was 55.2 per cent in first week of December when moisture content was 38.8 ± 1.3 % at low elevation; while at mid elevation the per cent germination was 36.6 in second week of December when moisture content was 36.6 ± 0.9 % in second week of December. Similarly at high elevation the germination was 51.2 per cent in second week of December when moisture content was 35.9 ± 3.8 % (Table 3). A significant variation was observed in seed germination behavior along an elevation gradient. The delay in germination was because of hard seed coat. The germination was significantly higher at low elevation compared to high elevation.

Various researchers have proposed seed color as an indicator of seed maturity. The color of oak seeds changed from dark green to dark brown at maturity indicated by the ease with which the seeds could be separated from the acorn cap with the commencement of browning of acorns. The seeds could be easily separated from the acorn cap from third week November onwards at lower and middle elevation and from first week of December on higher elevation site. The weight of seeds was significantly high at higher elevation compared to lower and middle elevation site**.** For fodder purpose, repeated lopping and cutting of trees has been carried out at lower elevation and middle elevation, which leads to decrease in weights of seed and seeds size. The mean seeds size was larger at lower elevation compared to middle elevation. These variations may be due to environmental condition operating at the same time of seed development (Chauhan and Verma 1995).

Across the sites, per cent moisture content of seeds ranged from 61.6 to 27.2 per cent during the study period and declined with each collection. Initial moisture content was significantly high at high elevation site compared to mid and low elevations. The maximum germination occurred when moisture content across all sites ranged between 35.9 and 38.8 ± 1.3 per cent. The best seed germination between 39.1

Table 2. Effect of collection dates on seeds characteristics of *Q. leucotrichophora* at different elevations

Collection dates	Seed color	Mean wt. of 100 seeds (g)			Mean no. of seeds/100g			Mean seed size		
		Low	Mid	High	Low	Mid	High	Low	Mid	High
W1O	Dark green	64.4±0.5	74.7±1.0	90.2±3.0	130.2±2.7	123.4±0.6	133.0±0.9	131.2±5.4	79.6±2.3	146.1±9.9
W3 O	Dark green	77.7±0.6	119.4±1.1	115.0±1.4	110.9±1.1	114.4±1.5	87.9±0.6	139.8±1.3	126.2±1.5	177.8±0.7
W1 N	Yellowish green	91.5±2.0	129.9±0.6	129.7±1.3	101.3±10.7	73.1±0.8	76.4±0.7	151.9±3.0	183.6±0.9	204.9±1.7
W3 N	Yellowish green	120.6±2.4	136.6±1.5	139.6±2.0	93.9±1.0	70.2±0.6	67.8±0.7	174.5±2.5	226.9±2.6	232.4±1.3
W1 D	Dark brown	143.1±1.6	124.9±0.8	144.2±1.0	90.7±1.8	68.8±0.9	53.1±0.7	190.1±2.1	234.9±3.3	251.9±0.6
W2 D	Dark brown	170.5±3.0	116.1±0.8	114.3±2.9	73.3±0.9	63.8±0.8	45.7±0.4	214.1±3.3	239.3±4.5	239.5±1.0
W3 D	Dark brown	175.9±1.6	70.7±1.8	64.7±0.6	67.5±0.4	62.0±0.4	33.8±2.3	228.4±2.4	232.7±1.1	236.8±2.7
W4 D	Dark brown	164.2±2.7	63.3±1.0	63.6±1.4	61.3±0.5	56.9±1.3	30.5±0.9	222.6±1.9	219.3±1.2	227.8±1.1

***** W1 O signifies 1st week October; W3 O signifies 3rd week October; W1 N signifies 1st week November; W3 N signifies 3rd week November; W1 D signifies 1st week December; W2 D signifies 2nd week December; W3 D signifies 3rd week December; W4 D signifies 4th week December

Table 3. Effect of moisture content on various germination parameters of *Q. leucotrichophora* across the collection dates

Date of collection	Moisture content (%)			Germination (%)			Germination capacity (%)		
	Site I	Site II	Site III	Site I	Site II	Site III	Site I	Site II	Site III
W1O	50.7 ± 1.5	57.8 ± 1.3	61.6 ± 1.2	16.8 ± 0.6	7.2 ± 0.4	10.4 ± 0.5	52.8 ± 0.4	20.0 ± 0.5	47.2 ± 1.2
W3 O	48.3 ± 1.5	55.6 ± 0.8	56.1 ± 2.5	26.4 ± 1.1	14.4 ± 0.3	31.2 ± 0.7	57.6 ± 0.7	23.2 ± 0.4	52.8 ± 1.7
W1 N	42.3 ± 0.6	45.5 ± 2.8	48.9 ± 0.1	37.6 ± 0.7	17.6 ± 0.5	36.8 ± 0.7	36.8 ± 1.2	32.0 ± 0.5	53.6 ± 1.0
W3 N	40.4 ± 2.2	41.8 ± 0.2	46.3 ± 0.3	47.2 ± 1.5	27.2 ± 0.6	40.8 ± 0.6	61.6 ± 1.0	44.8 ± 0.9	55.2 ± 0.8
W1 D	38.8 ± 1.3	39.8 ± 0.3	42.2 ± 0.6	55.2 ± 1.2	32.8 ± 0.4	44.8 ± 0.2	64.8 ± 1.0	48.0 ± 0.9	56.8 ± 9.3
W2 D	34.7 ± 2.1	36.6 ±0.9	35.9 ± 3.8	53.6 ± 1.1	36.8 ± 0.5	51.2 ± 0.8	67.2 ± 0.8	44.0 ± 1.1	58.4 ± 0.8
W3 D	33.1 ± 2.5	34.0 ± 0.4	30.2 ± 0.2	42.4 ± 0.7	26.4 ± 0.5	41.6 ± 0.6	55.2 ± 0.4	39.2 ± 0.6	54.4 ± 1.1
W4 D	31.1 ± 0.8	32.5 ± 0.7	27.2 ± 1.5	39.2 ± 0.5	24.0 ± 0.5	27.2 ± 0.6	48.8 ± 0.4	36.8 ± 0.9	47.2 ± 0.5

***** W1 O signifies 1st week October; W3 O signifies 3rd week October; W1 N signifies 1st week November; W3 N signifies 3rd week November; W1 D signifies 1st week December; W2 D signifies 2nd week December; W3 D signifies 3rd week December; W4 D signifies 4th week December

and 41.7 per cent moisture content has also previously been reported by Bhatt and Ram (2005). Moisture content of oak acorns has been proposed a useful indicator of viability retention and germination (Griffin 1971, Schopmeyer 1974). Rao (1984), recorded that peak seed fall in *Q. leucotrichophora* at a site located at 1818 m elevation commenced from January and continued upto March-April. The maximum germination under laboratory conditions at 25°C and 30°C ranged between 80-100%. The seed size was 272.5 mm and seed weight 2034.5 mg (fresh) and 1463.2 (dry) mg seed^{-1}. In the present study, the maximum germination was much lower (30-40%) under similar conditions and time of commencement of natural seed fall earlier by 45 days starting from November 2nd week and attaining a peak by December end. The study highlights that conservation of slow growing banj-oak is the biggest challenge against continuous anthropogenic disturbances as well as changing climatic conditions.

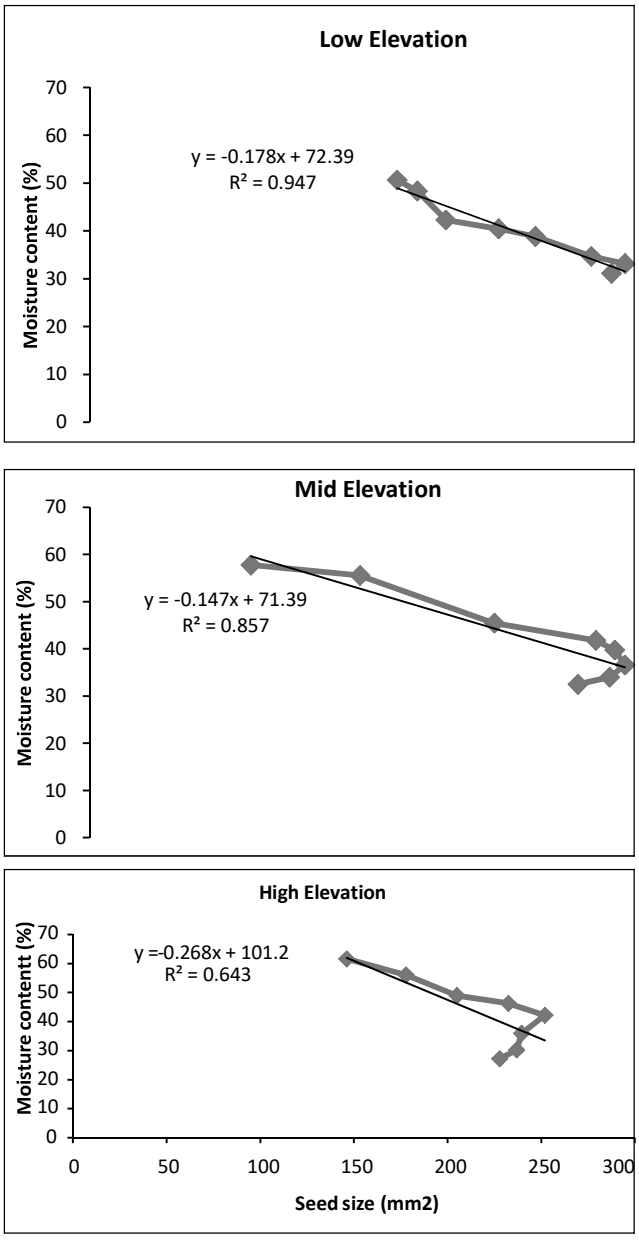

Fig. 1. Relationship between seed size (mm^2) and moisture content (%) of *Q. leucotrichophora* at low, mid and high elevation

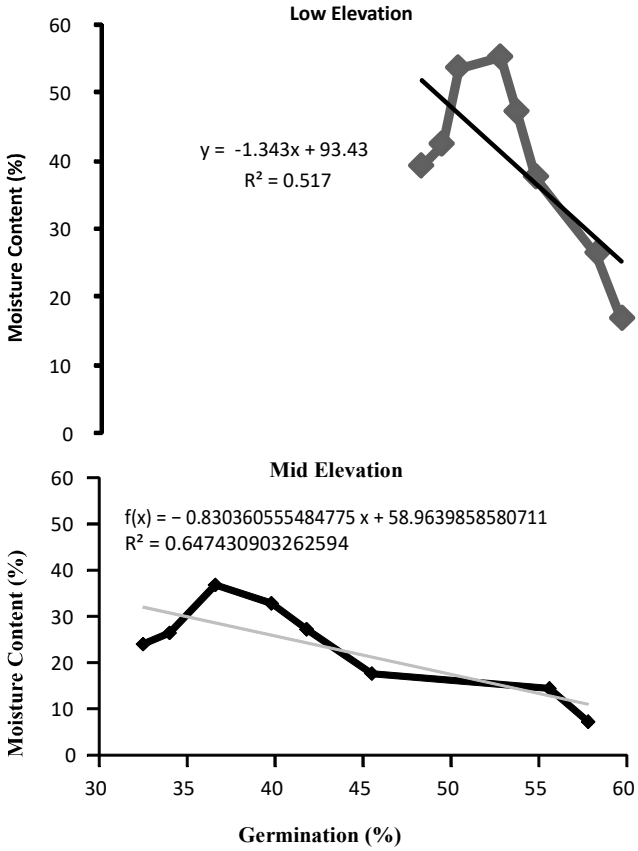

Fig. 2. Relationship between moisture content (%) and germination (%) of *Q. leucotrichophora* at low and mid elevation

CONCLUSION

The color change of seeds from dark green to dark brown resulted in the ease of separation of acorns from the cap and the moisture content range between 35.9 and 38.8 percent appear to be reliable indicators of maturity in *Q. leucotrichophora* along its elevation range. The time of seed maturation in *Q. leucotrichophora* was earlier when compared with earlier studies and germination declined due to excessive lopping and infestation of seeds. This could also be a yearly variation impacted by climatic irregularity.f

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Received 12 December, 2021; Accepted 21 March, 2022

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