Indian Journal of Agricultural Sciences **86** (8): 1086–91, August 2016/Article

Phenology and growth performance of Himalayan birch (*Betula utilis*) in Kashmir Western Himalayas along the different altitudinal gradients

NASEER A MIR[1], T H MASOODI[2], ASHFAQ A MIR[3], HINA KHAN[4], P A SOFI[5],
FEHIM JEELANI WANI[6] and OMAR BIN HAMEED[7]

Sher-e-Kashmir University of Agriculture Science and Technology of Kashmir,
Binhama, Jammu and Kashmir 191 121

Received: 28 April 2016; Accepted: 18 May 2016

ABSTRACT

The phenological events, height class distribution, volume and biomass of Himalayan birchor *bhojpatra* (*B. utilis* D. Don) were monitored along the altitudinal gradient in distinct ecological settings at Sindh and Tangmarg forest divisions in western Himalayas, Kashmir. The observations recorded revealed high synchrony throughout the altitudinal gradients, especially for bud set, bud burst, peak flowering and seed maturation. All the phenological events began early at lower elevation as compared to higher elevation. The timing of phenophases along the altitude was governed by the timing of snow-melt which is usually responsible for early phenological changes in the northern alpine habitats. The height, volume and biomass showed a decreasing trend with increasing altitude at both the sites. Higher number of trees (116.71 trees/ha) with maximum height, volume (112.38 m^3/ha) and biomass (57.31 tonnes/ha) were recorded at 3 000 – 3 200 m asl. The values for all these parameters decreased with increasing altitude from 3 200–3 400 and 3 400–3 600 m amsl, respectively. The short growing seasons, reduced air and soil temperature (an adiabatic effect), increased exposure to wind, lower availability of nutrients and increased exposure to frost are some of the common features of high altitude niches which greatly influences the growth of the existent vegetation.

Key words: *Betula utilis*, Biomass, Flowering, Height, Phenophases, Volume

Himalayan birch or *bhojpatra* (*Betula utilis* D. Don) (*bhojpatra* birch) forms treeline vegetation all along the Himalayas, and extensive stands of this species can be found on northern/southern shady slopes and ravines (TISC 2002). It is the only broadleaved angiosperm tree species in the Himalayas which dominates an extensive area at subalpine altitudes (Zobel and Singh1997). *Betula* spp. show a high freezing tolerance which enables them to form a treeline in the Himalayas (TISC 2002). The species is endemic to Arunachal Pradesh, Himachal Pradesh, Jammu-Kashmir, Sikkim and Uttarakhand. However, the massive overexploitation for fuel wood, fodder and medicines (Sharma *et al.* 2010) as well as the unscientific management of this species has caused loss of habitat in many of its native groves in the entire Himalayan range (Cuirong and Mark 1998). The species has already been declared as critically endangered in Kashmir by Environmental Information System (ENVIS), Centre on Conservation of Medicinal Plants and Foundation for Revitalization of Local Health Traditions (FRLHT), Bengaluru (Anonymous 2010). The phonological events, volume and biomass distribution of *B. utilis* stands in the Kashmir Himalayas were not studied. Here we report the vegetative and reproductive events of the *B. utilis* dominant stands in Sindh and Tangmerg Forest Divisions of Kashmir Valley. The *B. utilis* forms treeline vegetation in these Forest Divisions between an elevation of 3 000 and 3 600 m amsl on south eastern and south western slopes.

Betula grows in between the timber line (3 000-36 000m amsl) producing excellent biomass that is used by community as medicinal plant. Betulin, a compound present in its wood has anticancer properties and can suppress growth of malignant melanoma, cancer of liver and lungs (Singh *et al.* 2012**)**. Besides it has karachic acid as one of the active ingredients which has aromatic and antiseptic properties (Sharma *et al.* 2010). The tree is also lopped for fodder, making agriculture tools, fuel wood and other wood based industries (Alam and Nizami 2014).

MATERIALS AND METHODS

The present study was concentrated along the three altitudinal gradients of 3 000–3 200 m, 3 200–3 400 and 3 400–3 600 m amsl in two *Betula* stands at Sonamarg (Sind Forest Division) and Khilanmarg (Special Forest Division Tangmarg). The Sindh Forest Division with the demarcated area of 37 901 ha lies between 34^{o} 72 and 34^{o} 282 north

---

[1,2,3,5,6,7](e mail: naseer mirl@gmail.com), Faculty of forestry, SKUAST. [4]ICAR, Krishi Anusandhan Bhavan-1 Pusa,New Delhi 110 012.

latitude74^{o} 422 to 75^{o} 262 to east longitude. The tract of the selected site in this forest division is extremely mountainous and full of ridges with rugged terrain. The altitude of this forest division ranges from 1 587 m near Harran to 5 248 m at Harmukh with dominant *Betula* stands forming their niche between 3 000–3 750 m asl. The study site is located between the altitudes of 3 000–3 600 m. The whole forest division forms a catchment area which drains into Sindh river with many smaller nallas from side valleys tributing to it. The Special Forest Division is spread over an area of 76 585 ha and located between 34^{o} 01.9742 North latitude and 74^{o} 22.0692 East longitude. The birch stands in this Forest Division at Khilanmarg lie on steep to very steep south facing slopes with an average inclination of 40^{o}. The Birch stands with an altitudinal range of 3 000–3 700m is surrounded by high mountains of Nanga Parbat and Harmukh mountains (>6 000m).

The study sites exhibits temperate climate experiencing four distinct seasons: a severe winter (December to February), a cold spring (March to May), a mild summer (June to August) and a pleasant autumn (September to November. The mean annual minimum (January) and maximum (July) temperature along the selected timberline ecotone ranges from –8.1 to 19.01°C and –4.4 to 17.6°C at Sonamarg and Gulmarg. The mean temperature of the warmest month is July with 22.0°C. The average annual precipitation at Sonamarg and Gulmarg varies from 932–1 050 mm and 1 049–1 100 mm out of which about 73 and 69% is recorded during winter and spring and the rest during autumn, respectively. The snow cover at the selected sites lasts for about 195 and 180 days/year.

The procedure used for determination of phenological characteristics was developed and modified from time to time (Shi *et al.* 2000). Phenological events of *B. utilis* were monitored along the three altitudinal gradients in distinct ecological settings of Sindh and Tangmarg forest divisions of Kashmir carried out at 10 days interval for 10 individual trees at every altitudinal gradient and described in different phases, viz. bud set, bud burst, flowering, leaf initiation, flowering dehiscence (male), seed formation, seed maturation, leaf tint and leaf fall.

For the height class distributions the vegetation of *Betula utilis* was grouped into: (a) Emergents (In this class, the largest trees reach between 60 - 100 cm in diameter and more than 20 m in height), (b) Upper and middle storey (Trees with less than 60 cm of diameter and height class of 15-20 m) and (c) Lower-storey (Trees smaller than 30 cm in diameter and up to 15 m in height. This class is further divided into two sub categories: - L1: Trees more than 15 cm of diameter and 10 m height and L2: trees with less than 15 cm diameter and < 5 m height) (Felfili 1997).

Volume of the standing trees was calculated by formula as:

$$V = \frac{\pi}{4} d^2hf$$

where h = tree height, d = diameter and f = form factor. Biomass of the Birch trees was calculated as:

Biomass = Volume × wood density (Wood specific density is 0.51(Philips 1994))

RESULTS AND DISCUSSION

Pheno-phases

The data in Table 1 summarizes pheno-phases and reproductive behaviour of *Betula utilis* along the altitudinal gradient at the selected sites in respective two forest divisions. The results envisage that the phenological events of the species overlap with each other. At lower altitude (3 000–3 200 m), the bud set starts from 1 to 10 of May followed by bud burst from 5 to15 May, flowering from 10 to 20 May, leaf initiation from 15 to 25 May, seed formation from 1 to 10 June and seed maturation from 10 to 20 September. The vegetative and reproductive phases of *B. utilis* were observed to be delayed by around 5 days at the middle altitudinal gradient of 3 200–3 400 m. The bud set at this altitude started from 5 to 15 May followed by bud burst from 10 to 20 May, flowering from 15 to 20 May, leaf initiation from 20 to 30 May, seed formation from 20 to 30 June, seed maturation from 15 to 25 September. Similarly, at upper altitudinal gradient phonological events were further delayed with bud set starting from 10 to 20 May followed by bud burst from 15 to 25 May, flowering from 20 to 30 May, leaf initiation from 25 May to 5 June, seed formation

Table 1 Vegetative and reproductive pheno-phases of *B. utilis* in western Himalayas along different altitudinal gradients

Reproductive and vegetative phases	Altitudes 3 000–3 200 m	 3 200–3 400 m	 3 400–3 600 m
Bud set	1–10 May	5–15 May	10–20 May
Bud burst	5–15 May	10–20 May	15–25 May
Flowering	10–20 May	15–25 May	20–30 May
Leaf Initiation	15–25 May	20–30 May	25 May – 5 June
Flowering dehiscence (Male)	15–25 May	20–30 May	25 May – 5 June
Seed formation	1–10 June	5–15 June	10–20 June
Seed maturation	10–20 Sep	15–25 Sep	25 Sep. – 10 Oct
Leaf tint	15–25 Sep	5–15 Sep	5–10 Sep
Leaf fall	25 Sep. –10 Oct.	15–30 Sep	10–25 Sep

Table 2 Height class distribution of *B. utilis* across the available aspects and altitudinal gradient in *Betula* dominant tree stands in central and north Kashmir

Altitude (amsl)	Sonamarg								Gulmarg			
	South East				South West				South West			
	Emergents (upper story/ha	Middle story (ha)	Lower story (ha)		Emergents (upper story/ha)	Middle story (ha)	Lower story (ha)		Emergents (upper story/ha)	Middle story (ha)	Lower story (ha)	
			L1	L2			L1	L2			L1	L2
3 000-3 200	117.00	135.56	235	300	112.14	133	225	328.57	121.00	143.50	231.43	364.67
3 200-3 400		108.60	390	648.5		102	329.4	641.1		107.33	357.4	818.5
3 400-3 600				444.44				411.11				455.56

L1= more than 15 cm diameter and 10 m height, L2= less than 15 cm diameter and 10 m height.

from 10 to 20 June, seed maturation from 25 September to 10 October. The observations revealed that vegetative and reproductive phases at this altitude were completed in 5 months and 10 days.

The spring phenophases are particularly sensitive to the temperature during late winter and early spring, which are also considered as accurate predictors of phenophase timing (Galan *et al.* 2005). The dry period (snow-free soil) during April/May initiates bud swelling in this species, but bud break only takes place after the average temperature rises above 5°C. If this is delayed, there is a longer period from initiation of swelling to breaking (Rai *et al.* 2011). Flowering occurred in July-August in most of the growth forms on alpine zone (Moser *et al.* 2010). Rawal *et al.* (1991) reported the similar trend of sprouting of *B. utilis* at elevations of 3 300 and 3 450 m. The delay in the leafing, flowering and fruiting at higher elevation is accounted by the cold spring but this does not delay the fruit maturation in late summers (Vashistha *et al.* 2009). The onset of flowering is crucial to the reproductive success of flowering plants particularly at higher elevations and in late flowering species, the entire seed production is often lost to colder or shorter summers rather than the average growing period (Henry and Molau 1997). In case of leaf fall a reverse pattern starting earlier by 10 September at upper altitude, 15 September at middle altitude and 25 September at lower altitude. Leaf fall in *B. utilis* can associated with the drop in temperature during autumn at the higher altitudes and later at lower altitudes. A longer leaf life span is associated with potentially higher carbon gain by the plant and more efficient nutrient use (Richardson *et al.* 2006). The preceding results reveal that phenological events are constrained at high altitudes by the short growing season and delimited by cold temperatures and snow cover. Thus the vegetative and reproductive cycles are accomplished more rapidly at high altitudes where snowfall occurs earlier and persists longer.

Height class distribution

Emergents / Upper class (plants/ha)

The emergent class with tree height of >20m exhibited a respective density of 117, 112 and 121 trees/ha at lower altitudinal gradient of 3 000–3 200 m at Sonamarg and Gulmarg, respectively. Contrary to this the emergent class of Birch trees were exclusively absent on other altitudinal gradients at both the selected sites (Table 2).

Middle story (plants/ha)

The plants under this category were present at lower and middle altitude and absent on upper altitude. The higher tree density of 135, 133 and 143 trees/ha were present on lower altitude in both the forest divisions of Sonamarg and Gulmarg at respective aspects. The number of trees in this height class was 108, 102 and 107 /ha at middle altitude on the respective aspect at Sonamarg and Gulmarg (Table 2).

Lower story (plants/ha)

This was the only class which represented at all the altitudes. The maximum numbers of trees in this class on respective aspects were 1 038, 970 and 1 175 trees/ha at middle altitude and minimum 444, 411 and 455 trees/ha at upper altitude in Sonamarg and Gulmarg forests, respectively (Table 2).

Height of the trees decreased with the increasing altitudes as indicated by short growing seasons, reduced air and soil temperature (an adiabatic effect), increased exposure to wind, and reduced supply of nutrients, increased exposure to frost, (Coomes and Allen 2007). The timing of leaf emergence and senescence may also effect the growth (height and diameter) as it is associated with remobilization of nutrients, particularly nitrogen and storage of photosynthesis (Lim *et al.* 2007). Our observations revealed a decrease in the plant size with an increase in altitude which is in accordance with the findings of Bresson *et al.* (2011) who reported a decrease in the plant size as an adaptation to increasing altitude. Decrease in plant height with increasing altitude results from slower growth rate that allows plants to use resources more efficiently in severe climatic environments and may prove beneficial for the species as the stem shortening allows plants to avoid the detrimental effects of the strong winds (Molina-Montenegro *et al.* 2012). The similar trend in the height classes with altitudes has been reported by Yaqoob and Nawchoo (2015) in *Ferula* *jaeschkeana* Vatke at several places across in Kashmir valley.

Stem volume and biomass

The data on stem volume and biomass of *Betula* trees are summarized in Table 3. At Sonamarg the maximum and minimum stem volume (193.27 and 27.87 m^3/ha and biomass 98.57 and 14.21 tonnes/ha) of *Betula* trees was recorded in the diameter class of >50 cm and 0-25 cm at lower and upper altitude on south eastern aspect, respectively, Similarly the maximum and minimum stem volume of 175.16 and 20.89 m^3/ha with biomass 89.33 and 10.65 tonnes/ha was recorded in diameter class >50 cm and minimum 0-25 cm, respectively on south western aspect. The similar trend was recorded at Gulmarg with maximum stem volume of 184.28 m^3/ha with biomass 93.38 tonnes/ha in the diameter class of >50 cm and minimum stem volume of 36.61 m^3/ha with biomass 18.67 tonnes/ha in the diameter class of 0-25 cm.

The mean values of the volume and biomass at both the sites showed the decreasing trend with increasing altitude, the maximum and minimum volume of 113.98 and 30.49 m^3/ha with biomass 58.13 and 15.55 tonnes/ha were recorded at Lower and upper altitude, respectively, (Fig 1).

Birch is the most important broadleaved tree species in many parts of the world especially Russia and Belarus with its potential role in commercial forestry. According to the yield tables of Schwappach (1903), silver birch reaches only a cumulative volume production of 389 m^3/ha at the age of 80 on the best sites in central Europe (MAI = 4.9 m^3/ha). In Nordic countries, birch is the most productive species of all the commercially important native broadleaved tree species. The high productivity, combined with straight and slender stems, is the main reasons why birch is the most important broadleaved tree species in forestry.

The maximum volume and biomass of *Betula* was recorded in >50 cm diameter class at lower altitude with subsequent reduction along the higher elevation. As expected the lower diameter classes depicted less volume and biomass at both the forest division. This might be due to the fact that DBH decreased with increasing altitude, with upper altitude representing only lower diameter class (Table 3, Fig 1). The reason behind decreased volume and biomass along the altitudinal gradient is highly correlated with decrease in DBH (Missanjo *et al.* 2013). Alam and Nizami (2014) documented the maximum volume of 0.15733 m^3/tree and biomass of 80.23 kg /tree in upper diameter class (above 20 cm) for *B. utilis* in Kalam forest division located in Khyber Pakhtunkhwa (KPK) province of Pakistan. Zianis *et al.* (2005) found that predicted stem volume of beech tree in diameter of 40 cm varied from 1.1 and 2.2 m^3/tree. Our results are in agreement with Ndema and Missanjo (2015), who found that average diameter and volume decreased corresponding with increasing altitude. The similar trend along the altitudinal gradient were documented by (Coomes and Allen 2007, King *et al.* 2013). Growth rate is found to decline with increasing altitude due to several reasons particularly recourses (Coomes and Allen 2007). Repola *et al.* (2006) has reported that under average growing conditions about 70% of the total biomass of a mature birch tree is allocated to the stem, 10 per cent to the crown (branches and leaves) and 20% to the stump and roots.

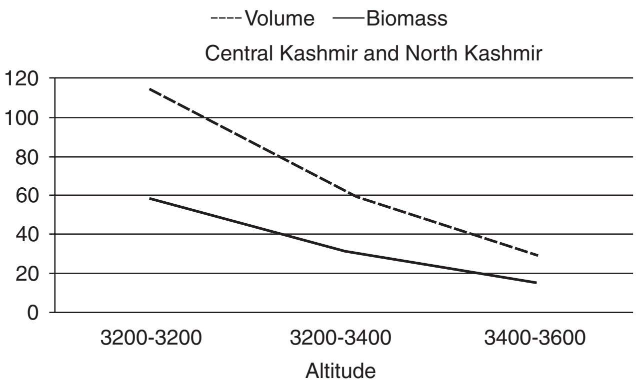

Fig 1 Average volume and biomass curve of *B. utilis* along the altitudinal gradient in *Betula* dominant tree stands in central Kashmir and north Kashmir.

Kitayama (2002) reported that above ground biomass decreased from 43.2 m^3 at 700 m to 3.4 m^3 at 3 100 m altitude on Mount Kinabalu, Borneo. It was suggested that increased nutrient availability and a longer growing season could underpin increased tree abundance, volume and biomass (Tape *et al.* 2006). Rundqvist *et al.* (2011) on the other hand, suggested that the observed increase may merely be a delayed re-expansion of trees following the "Little Ice-age" that ended in the early twentieth century. The mountain Birch forest is a major source of biomass and sink for

Table 3 Volume and Biomass production of *B. utilis* across the available aspects and altitudinal gradient in *Betula* dominant tree stands in central and north Kashmir

		Sonamarg							Gulmarg				
Altitude	Parameters	South East			South West			Sub	South West			Sub	Grand
(amsl)		0-25	25-50	>50	0-25	25-50	> 50	Mean	0-25	25-50	> 50	Mean	Mean
3 000–3 200	Volume m^3/ha	75.83	78.88	193.27	57.55	64.8	175.16	107.58	94.86	82.01	184.28	120.38	113.98
	Biomass t/ha	38.67	40.23	98.57	29.35	33.05	89.33	54.87	48.38	41.83	93.98	61.40	58.13
3 200–3 400	Volume m^3/ha	70.81	51.79		50.97	48.3		55.46	87.43	50.39		68.91	62.19
	Biomass t/ha	36.11	26.41		25.99	24.63		28.29	44.59	25.7		35.15	31.72
3 400–3 600	Volume m^3/ha	27.87			20.89			24.38	36.61			36.61	30.50
	Biomass t/ha	14.21			10.65			12.43	18.67			18.67	15.55

atmospheric CO_2 in the Tornetrask area (Christensen *et al.,* 2007). Wang *et al.* (2000) reported that the stem of paper Birch contributed more than 70% of the total biomass. The stem biomass of *Gmelina arborea* contributed 80% of the total biomass (Jonathan 2004).

The present study has revealed that altitude has a clear effect on phenology, height, volume and biomass of *Betula utilis*. Total volume and biomass of the tree was found to be dependent on the diameter and height of the tree. The phenological events started earlier at lower altitude except the leaf fall, which started earlier from upper altitude, total height, volume and biomass decreased with an increase in altitude. So it is recommended that for the collection of abundant viable seeds, they should be collected from lower altitude (3 000-3 200 m amsl) from 10-20 September in the region.

REFERENCES

Alam A and Nizami S M. 2014. Assessing biomass expansion factor of Birch Tree *Betula utilis* D. Don. *Open Journal of Forestry* **4**: 181–90.

Anonymous. 2010. Medicinal plant species of conservation concern identified for Jammu and Kashmir (JK) http://envis.frlht.org Environmental Information System (ENVIS) Centre on Conservation of Medicinal Plants, (Foundation for Revitalisation of Local Health Traditions) Bengaluru.

Bresson C C, Vitasse Y, Kremer A and Delzon S. 2011. To what extent is altitudinal variation of functional traits driven by genetic adaptation in European oak and beech? *Tree Physiology*. **31**(2): 1 164–74.

Christensen T R, Johansson T, Olsrud M, Strom L, Lindroth A, Mastepanov M, Malmer N and Friborg T. 2007. A catchment-scale carbon and green house gas budget of a subarctic landscape. *Philosophical Transactions of the Royal Society* **365**: 1 643–56.

Coomes D A and Allen R B. 2007. Effects of size, competition and altitude on tree growth. *Journal of Ecology* **95**: 1 084–97.

Cuirong L and Mark E 1998. Sediments of time: environment and society in Chinese history. Cambridge University Press, Cambridge, UK: p 65.

Felfili J M. 1997. Diameter and height distributions in a gallery forest tree community and some of its main species in central Brazil over a six-year period (1985-1991). *Revta brasil Bot., Sao Paulo* **20**(2): 155–62.

Galan C, Garcia-Mozo H, Vazquez L, Ruiz L, Diaz C, Guardia de L and Trigo M M 2005. Heat requirement for the onset of the Olea europaea L. pollen season in several sites in Andalusia and the effect of the expected future climate change'. *International Journal of Biometeorology* **49**: 184–8.

Henry G H R and Molau U. 1997. Tundra plants and climate change: the International Tundra Experiment (ITEX). *Global Change Biology* **3**(1): 1–9.

Jonathan C O. 2004. Above-Ground Biomass Production and Biomass Equations for Even-Aged *Gmelina arborea* (ROXB) Plantations in South-Western Nigeria. *Biomass and Bioenergy* **2**: 39–46.

King G M, Gugerli F, Fonti P and Frank D C. 2013. Tree growth response along an elevational gradient: climate or genetics? *Oecologia*, doi: 10.1007/s00442-013-2696-6.

Kitayama K. 2002. Ecosystem structure and productivity of tropical rain forests along altitudinal gradients with contrasting soil phosphorus pools on Mount Kinabalu, Borneo. *Journal of Ecology,* **90**(1): 37–51.

Lim P O, Kim H J and Nam H G. 2007. Leaf Senescence. *Annual Review of Plant Biology* **58**(1): 115–36.

Missanjo E, Kamanga-Thole G and Manda V. 2013. Estimation of genetic and phenotypic parameters for growth traits in a clonal seed orchard of *Pinus kesiya* in Malawi. *ISRN Forestry*, Article ID 346982.

Molina-Montenegro M A, Penuelas J, Munne-Bosch S and Sardans J. 2012. Higher plasticity in ecophysiological traits enhances the performance and invasion success of *Taraxacum officinale* (dandelion) in alpine environments. *Biol. Invasions* **14**(2): 21–33.

Moser L, Fonti P and Buntgen U. 2010. Timing and duration of European larch growing season along altitudinal gradients in the Swiss Alps. *Tree Physiology* **30**: 225–33.

Ndema A and Missanjo E. 2015. Tree growth response of pinus oocarpa along different altitude in Dedza mountain forest plantation. *Agriculture, Forestry and Fisheries* **4**(1): 24–8.

Philips M S. 1994. *Measuring Trees and Forests,* 2nd ed, p 120. CAB International, Wallingford.

Rai I D, Bharti R R, Adhikari B S and Rawat G S. 2011. Structure and functioning of timberline vegetation in the western Himalayas: A case study. *High altitude rangelands and there interfaces in hind Kush Himalayas,* pp. 91–107.

Rawal R S, Bankoti N S, Samant S S and Pangtey Y P S. 1991. Phenology of tree layer species from the timberline around Kumaun in Central Himalaya, India. *Vegetatio* **93**: 109–18

Repola J. 2006. Models for vertical wood density of Scots pine, Norway spruce and Birch stems, and their application to determine average wood density. *Silva Fennica* **40**(4): 13.

Richardson A D, Bailey A S, Denny E G, Martin C W and O'Keefe J. 2006. Phenology of a northern hardwood forest canopy. *Global Change Biology* **12**: 1 174–88.

Rundqvist S, Hedenas H, Sandstrom A, Emanuelsson U, Eriksson H, Jonasson C and Callaghan, T V. 2011. Tree and shrub expansion over the past 34 years at the tree-line near Abisko, Sweden. *Ambio*. doi:10.1007/s13280-011-0174-0.

Sharma P P, Roy R K and Gupta D. 2010. Pentacyclic Triterpinoids from *Betula utilis (D.Don)* and *Hyptis suaveolens*. *International Journal of Pharmaceutical Technology Research* 2 (**2**): 1 558–32.

Shi F, Li J, Zu Y and Nie S. 2000. Ecology and biology characteristics of white birch resources in northeast China. (*In*) Tree Sap II, pp 13–6. Terazawa, M (Ed). Hokkaido University Press, Sapporo.

Singh S, Yadav S, Sharma P and Thapliyal A. 2012. *Betula utilis*: A potential herbal medicine. *International Journal of Pharmaceutical & Biological Archives* **3**(3): 493–8.

Tape K, Sturm M and Racine C. 2006. The evidence for shrub expansion in Northern Alaska and the Pan-Arctic. *Global Change Biology* **12**:686–702.

TISC (Tree Improvement and Silviculture Component).2002. *Forest and Vegetation Types of Nepal.* TISC Document Series 105, Department of Forest, Kathmandu, Nepal.

Vashistha R K, Rawat N, Chaturvedi A K, Nautiyal B P, Prasad P and Nautiyal M C. 2009. An exploration on the phenology of different growth forms of an alpine expanse of North-West Himalaya, India. *New York Science Journal* **2**(6): 29–41.

Vitasse Y, Porte A J, Kremer A, Michalet R and Delzon S. 2009. Responses of canopy duration to temperature changes in four temperate tree species: relative contributions of spring and autumn leaf phenology. *Oecologia* **161**: 187–98.

Wang J R, Letchford T, Comeau P and Kimmins J P. 2000. Above and below ground biomass and nutrient distribution of a paper birch and subalpine fir mixed-species stand in the sub-boreal spruce zone of British Columbia. *Forest Ecology and Management* **130**: 17–26.

Yaqoob U and Nawchoo I A. 2015. Impact of habitat variability and altitude on growth dynamics and reproductive allocation in *Ferula jaeschkeana* Vatke. *Journal of King Saud University – Science* 1–10.

Zianis D, Muukkonen P and Mencuccini R M M. 2005. Biomass and stem volume equations for tree species in Europe. *Silva Fennica Monographs* 4,63 p.

Zobel D B and Singh S P. 1997. Himalayan forests and ecological generalizations. *Bio Science* **47**: 735–45.