The present study has identified and mapped suitable sites for aerobic rice cultivation in eastern India. Suitability criteria model is proposed and the rice agro-environment has been further classified through computation of RAI from climatic data to harness the upland potential of India which is otherwise low productive. However, further research is needed to identify suitable aerobic rice varieties for different rice ecosystems.

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Lichenometric studies in vicinity of Pindari Glacier in the Bageshwar district of Uttarakhand, India

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The present study relates the size of the lichen thallus to the minimum age of the exposure of the surface on which it grows which consequently helps in assessment of the minimum age of the glacier retreat. The study deals with the crustose lichen *Rhizocarpon geographicum* having radial growth with a slow growth rate of 0.2 mm/year, and growing frequently in the vicinity of the Pindari Glacier. The calibrated approximate age of the surface exposed at a distance of 1 km from the glacier snout ranges from 550 to 600 years. The method is cheap, easy and applicable to date surface more than 500 years.

Keywords: Dating, lichenometry, Pindari Glacier, *Rhizocarpon geographicum*, Uttarakhand.

LICHENOMETRIC technique is useful in dating moraine ridges on recent glacier forelands in alpine regions. The method was originally developed and used by Beschel[1,2]. Glaciers are recognized as being among the most sensitive indicators of climate change, advancing substantially during climate cooling and retreating during climate warming. Lichens due to their slow growth rate and uniform growth size, help in dating the exposure time of the sequences of the rock forming glacier moraines due to retreat of the glacier thus providing the approximate time of glacier retreat. The study is based on lichen size/age correlation and lichen population distribution and involves the measurement of large specimens growing on large

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boulders that are supposed to be unaffected by the prevailing climatic conditions as well as human and animal interferences. Field studies of climate change impact in India can be conducted by initiating lichenometric studies in relation to climate change. Therefore, the Pindari Glacier of Kumaon Himalaya is being studied and an attempt has been made to evaluate the minimum time of exposure of the moraine from 1 km towards snout position with the help of lichens.

In the present study, a lichen of known growth rate is selected to date recent glaciation activity in the Pindari Glacier. The glacier is situated in the upper reaches of Kumaon Himalayas, to the southeast of the NandaDevi at an altitude of 3660 m and lies at about 30°15.30″N lat. and 79°13′–80°2″E long., bordering the northern mountainous region Danpur patti in the Bageshwar district of Uttarakhand. It is formed between Nandakheth and Nandakot mountains and joined by the Bankattia Glacier from the eastern Bankatti snow peaks. The glacier belt ranging from 4000 to 6000 m constitutes the famous Pindari pass, which opens the communication between Martoli in Milam valley of Johar patti and Danpur. The Pindari Glacier ends at an arbitrary point, which has been designated 'zero-point'. The glacier was first visited by R. Strachey[3] who gave a general description of the glacier (Figure 1).

Dating range depends on specific species and environmental factors. In temperate environments, some foliose forms might have survived for about 150 years, minute crustose forms can provide dating of 400–600 years and at high latitudes, dating may exceed 1000 years[4]. Absolute dating is based on the size of the largest surviving lichen. Therefore, reference to their specific details should be taken as minimum approximations only. Other factors leading to lichen mortality and renewed colonization are: competition for growing space on the rock surface, vegetation growth, weathering and geomorphologic processes.

The most common lichen growing on the slope boulder is *Rhizocarpon geographicum* (L.) DC. Among *Xanthoria elegans* (Links.) Th. Fr., *Dimelaena oreina* (Ach.) Norm., and *Lecanora muralis* var. *muralis* (Schreb.) Rebenh. *em.* Poelt, it is one of the most frequently used yellow–green coloured crustose lichen in lichenometry. Other lichen species growing in the vicinity of the glacier were avoided as these dark brown, black, grey species are not uniform in their growth.

For reliable results require that some conditions have to be fulfilled; the rocky faces should have been without lichen growth before lichen colonization and there should be uniform habitat conditions for a very long period.

Lichenometry appears to be superior to many other techniques; it attempts to date glacial deposits in the most accurate way. The technique is easy, cheap and can be applicable to date surfaces more than 500-years-old where radiocarbon dating is least efficient.

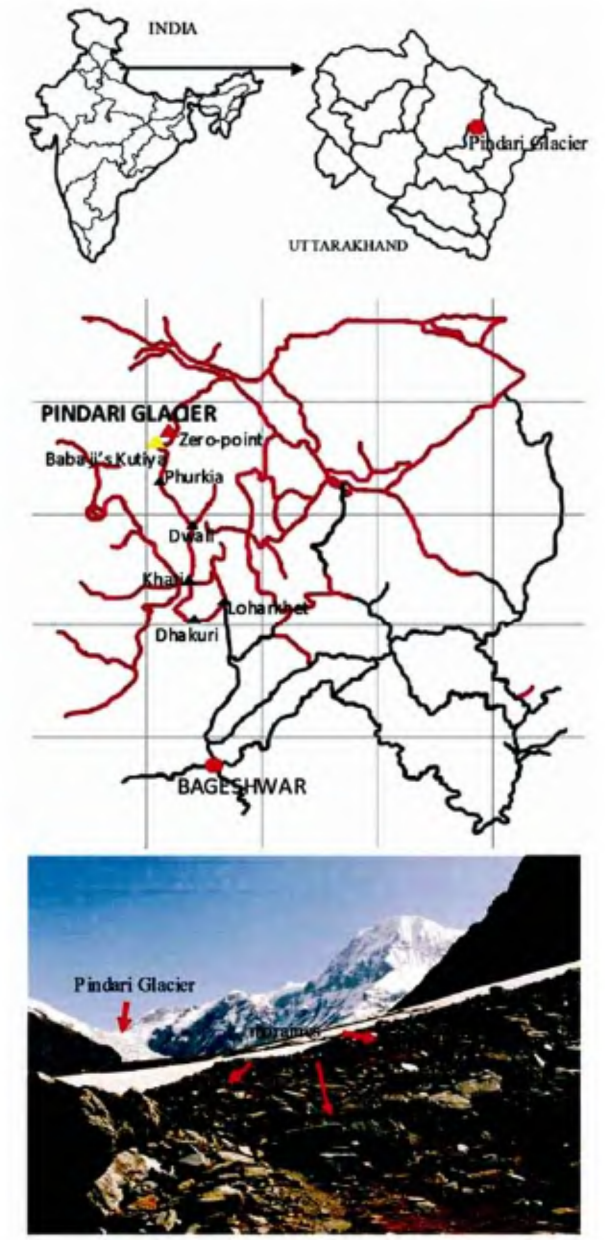

Figure 1. Location of the Pindari Glacier (map not to scale).

In alpine environments, growth of *R. geographicum* is very slow, i.e. 0.2 mm/year (ref. 5) and lives to a considerable age. Morphologically, the lichen comprises discrete areolae that contain cells of alga *Trebouxia*, located on a fungal medulla, which is attached to the substratum and extends into a black algal-free marginal zone around the thallus called hypothallus. Primary areolae near the edge of the hypothallus may develop from free-living algal cells on the substratum that are trapped by the hypothallus whereas secondary areoles may develop from zoospores produced within the thallus, thus ultimately resulting in the radial growth of *Rhizocarpon* (Figure 2).

A distance of 1 km (horizontally as well as vertically) from Baba ji's Kutiya to the zero-point is considered in

the vicinity of the Pindari Glacier for conducting the lichenometric study. There was a huge landslide near the snout and was considered to be a disturbed area; so the last sampling range selected was the zero-point. The entire area shows a gentle slope from zero-point to Baba ji's Kutiya that continues to increase in steepness beyond the sampling area. The samples selected for the study were predominantly found growing over the smooth exposed upper surface of the large boulders, rocks, stones and moraines that were situated apart from the trekking route to the glacier. The sampling sites were undisturbed as the boulders, rocks, stones and moraines were fixed and to a certain extent buried in the ground. Also, the tufts of grasses around the boulders indicated the long-standing position of the boulders in their places. The exposed plateau in the vicinity of the glacier clearly indicates that the boulders must have resulted from glacier retreat and not from landslides or debris flows.

The sampling area has been divided into 21 transverse sections or ranges that separate from each other by a constant distance of 50 m. By taking into consideration, the maximum number of largest round lichen thalli of *R. geographicum* in each range, the minimum age of the glacier retreat is found out by applying the formula:

$$\frac{1\times \text{Thallus size (mm)}}{0.2\ \text{(mm)}}.$$

In the laboratory, only the largest one was included in the calibration data sheet. There are usually two ways to measure the diameter of the lichen thallus; either by considering the outer boundary of the thallus as the diameter or by taking the inner boundary as the thallus size. The former generally does not give correct measurements, since neighbouring species may tend to fuse with the sample and give the appearance of an intact thallus thus providing anomalous results. In the present study, the inner diameter is taken as the thallus radial growth size and special attention is given to the hypothallus of the sample which circumscribed the main thallus thereby increasing the accuracy of measurement.

Whenever possible, we have chosen at least six large lichen thalli at each horizontal range (transverse section) and then delineated their thallus shape by covering with a transparent paper in the field. A maximum number of 30 samples were traced on boulders followed by 18 and 15 samples on rocks and moraine respectively.

It has been worked out from the study on glaciers that the yellow–green coloured *R. geographicum* is the most widely distributed lichen species[6] along with some other species of *Lecanora* and *Lobothallia* in the vicinity of the Pindari Glacier. The measurement was performed only on *R. geographicum* species due to its known growth rate and approximately circular thallus growth. A number of patches of that species have been reported and the diameter of the largest thalli is recorded by taking into account their longest axis (diameter) and distance from the glacier.

It was observed that there is a distinct positive correlation of pattern of size of thallus with the approximate age of the exposed surface ($r^2 = +0.998$ at $p < 0.05$) and its distance from the glacier snout ($r^2 = +0.909$ at $p < 0.05$). The boulders located at 1 km away from the glacier's terminus having lichen thallus diameter ranges between 110 and 120 mm resulted in the calibration of minimum age of exposure of the boulder as 550–600 years. The assumed nearest distance of 50 m from the zero-point contains minimum number of lichen thallus with size too small to measure. However, at least three representative samples of 15 mm diameter estimate the age of the exposed moraine as 75 years. The 10 transverse sections (8–17) falling under 700–200 m were almost barren in context of lichens. Thus due to scarcity of proper substratum (large boulders and rocks) for lichen growth in these ranges, the measurement was based on a few lichen thalli reportedly growing over stones. Based on five representative samples, the estimated surface minimum exposure age of the long distance of 400 m is between 200 and 250 years. The overall calibrated age of the exposed long distance of 1 km is provided in Figures 3 and 4, and Table 1.

In India, few studies have been performed in Himachal Pradesh and Garhwal Himalaya on various aspects of

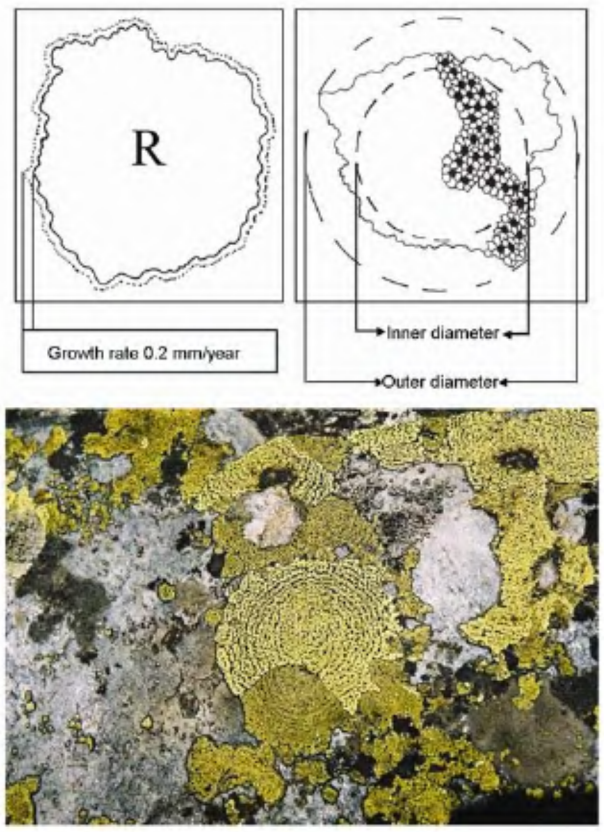

Figure 2. *Rhizocarpon geographicum* (L.) DC., a widely used lichen species in lichenometry.

Table 1. Calibrated data of lichenometric study in the vicinity of the Pindari Glacier

Horizontal range (transverse section)	Samples	Distance from glacier	Substrate	Thallus size range (mm)	Approximate age of surface (yrs)
1	6	1 km (Baba Ji's Kutiya)	Boulders	110–120	550–600
2	6	950 m	Boulders	100–110	500–550
3	6	900 m	Boulders	90–100	450–500
4	6	850 m	Boulders	80–90	400–450
5	6	800 m	Boulders	70–80	350–400
6	6	750 m	Rocks	60–70	300–350
7	6	700 m	Rocks	50–60	250–300
8, 9, 10, 11, 12, 13, 14, 15, 16, 17	5	700–200 m	Stones	40–50	200–250
18	6	150 m	Rocks	30–40	150–200
19	6	100 m	Moraines	20–30	100–150
20	6	50 m	Moraines	15–20	75–100
21	3	50–zero point	Moraines	15	75

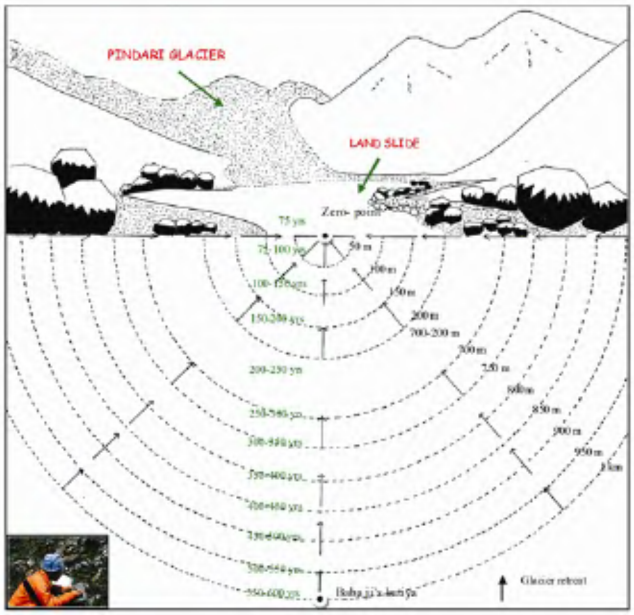

Figure 3. Lichenometric study performed in the vicinity of Pindari Glacier.

lichenometry[6–8]. In the Central Himalaya, the Pindari has been the only glacier studied in detail during the past 160 years by many glaciologists[2,9–11]. But the minimum time period of the exposed moraine near the Pindari terminus was undertaken for the first time with the help of lichens during the first week of May 2007. The minimum exposed period of the substrata 1 km away from the snout, 600-years-old revealed that the glacier area from 1 km onwards has been exposed 600 years ago.

The presence of grass-covered moraines and shrubby vegetation in the vicinity of the glacier suggests that the Pindari Glacier has not advanced in the recent past. Increase in temperature and less precipitation are equally attributed to the recession of the glacier over a period of time. Considerable reduction in the volume of the glacier ice is exemplified by the presence of the fairly well-exposed faces of the lateral moraines.

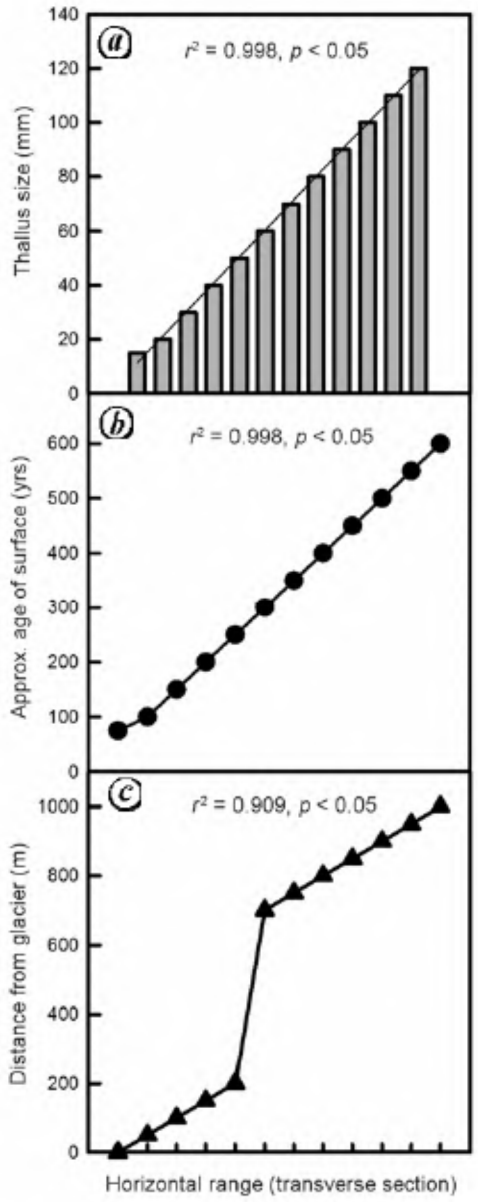

Figure 4. Growth curve of lichen thalli in relation to age of exposed surface and the distance. ***a***, Thallus size; ***b***, Approximate age of surface; ***c***, Distance from glacier.

Earlier studies on glaciers were based on the database and calibrated growth rate of the species to date the surfaces, which generally requires a long time period. The present technique is simple, concise and can generate a theoretical background for implementing future strategies for using lichens in climate change studies.

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Inter- and intra-generic grafting in seaweeds in the Indian coasts

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Traditionally, grafting has been effective among higher plants. An attempt was made to graft some commercially important red seaweeds in the shallow waters at Thonithurai, Mandapam on the south-east coast of India to study the possible effects of grafting on seaweeds. Lower group plants of *Kappaphycus alvarezii* (*Ka*), *Gelidiella acerosa* (*Ga*), *Gracilaria verrucosa* (*Gv*) and *Gracilaria dura* (*Gd*) were selected for intergeneric grafting. The graft combinations were *Ka* + *Ga*, *Ka* + *Gv*, *Ka* + *Gd*, *Ga* + *Gv* and *Gv* + *Gd*. Similarly, three different colour strains (green, red and conventional) of *Ka* were selected for intrageneric grafting. Four different combinations were made: R + C, R + G, G + C and R + G + C. Among intergeneric grafted plants, *Ka* + *Ga* was found attached after 29 days but could not survive after 60 days from the date of grafting whereas the plants of intrageneric grafts showed more than 80% survival rate. Grafts of R + C and G + C were attached after 3 weeks and R + G + C were attached after 25 days. There was good difference in their growth rate and the biomass yield. R + G + C gave an average yield of 443.3 g fr. wt plant^{-1}. Analysis of variance (ANOVA) showed that intrageneric grafts between different strains of *Ka* had significant variations in their daily growth rate (*F* ratio = 1.20096E and *P* = 0.000). This study supports the feasibility of intrageneric grafting in seaweeds. Due to fast and easy regenerative potential, high grafting success is achievable.

Keywords: Intergeneric grafting, intrageneric grafting, polysaccharide, red seaweeds, regeneration.

THE red seaweeds *Kappaphycus alvarezii* (Doty) Doty (*Ka*), *Gelidiella acerosa* (Forsskal) Feldmann *et* Hamel (*Ga*), *Gracilaria verrucosa* (Hudson) Papenf. (*Gv*) and *Gracilaria dura* (C. Agardh) J. Agardh (*Gd*) are in great demand for their cell wall polysaccharides. Because of fast growth rate, ease of reproduction and being an important source of κ-carrageenan, the cultivation of *Ka* has obtained worldwide attention[1]. The other seaweeds are significant sources of biomass for agar extraction in many countries[2–5]. The agar obtained from *Ga* and *Gd* is of superior quality and is widely used in a number of preparations in biomedical, biotechnological, pharmaceutical, food, cosmetic and paper industries[6–9]. The agar obtained from *Gv* is usually used in the food industry[10].

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