Gender variation in a threatened and endemic palm *Trachycarpus takil* Becc.

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A detailed study of flowering and fruiting in endemic and threatened palm, *Trachycarpus takil* was carried out. Earlier reports on the male and female concept of the plant were found incorrect; the plant is not perfectly dioceous. Gender expression in this species is not stable and it was noted that there is a tendency of young plants to behave as male which subsequently changes the sex from male to bisexual and female on ageing. It was also noted that the species is evolutionarily at superior stage and basically planned to outbreed but if the chances of cross pollination fails, the plant has capacity to develop pollen grains in staminodes to ensure the sexual reproduction.

Keywords: Endemic palm, gender variation, flowering, fruiting.

TRACHYCARPUS *takil* Becc. (Arecaceae) is a threatened palm, endemic to Kumaon Himalaya[1–5]. It was first discovered from the montane oak forest of Kumaon Hills by Madan[6] and identified as *Chamaerops khasyana* Griffith, and later resurveyed by Gibbons and Karmelk[7]. During the British period this species was reported from five other localities of Kumaon[6,8–11]. At present it is known to grow only in three localities of the region[2,12,13]. Two small populations with less than 500 individuals are found in Pithoragarh District. The third population is found in the Almora District of Kumaon Hills and is nearly on the verge of extinction due to forest fire[4,13]. The young plants are cut by local people for making ropes, brooms and curd churners before they flower. Of the two populations growing in Pithoragarh District, one is at Gini–Ratapani at the base of the Kalamuni forest and the other population is found growing in Thalkedar forest (with mostly juvenile plants). Possibilities of a few more populations in Kumaon and Nepal were postulated on the basis of information gathered from local people[13]. Furthermore, earlier reports on its cultivation as an ornamental in several hill stations of Kumaon[1–3,10,14,15] are found incorrect; such reports refer to *T. fortunei* (Hook.) Wendl.[13]. In these two wild populations, only five mature plants were noticed in the Gini–Kalamuni area. It is hoped that if not cut by the locals, a few may attain flowering in a couple of years, but no flowering plant was noticed in the second locality. Among these mature plants only one was seen flowering during the study period (Figure 1 *b*), growing near an inaccessible rock. Six more flowering plants (Figure 1 *a*, *c–e*) were seen growing in cultivated land or near human settlements at Munshyari town, Barabe village and Lamgarah. The last two localities at the fringe of Thalkedar forest, the type locality, with almost the same climatic and soil conditions. The status of this endemic palm has been disputed[12,13,15]. However, based on population studies and threat assessment according to IUCN norms[16], it certainly deserves a place in the *Red Data Book*. Conservation strategies of this palm have been discussed earlier[13].

The species was described by Beccari[9] on the basis of a single male plant raised by him in his garden at Florence (Italy) from the seeds supplied by Duthie in 1886 from Takil hill (presently known as Thalkedar), near Pithoragarh, Kumaon Himalaya, Uttarakhand. Female flowers were described from a different plant[2,9,10]. From the above description and literature review it was believed that the plants are dioecious[1,10,13,17–20]. Fruit-producing plants were considered as female and plants with dried spadices in late season as male. Furthermore, a review of the genus *Trachycarpus* reveals that four different terms were used by different authors[20–26], which was often overlooked at the time of describing of *T. takil*.

While conducting population studies for conservation status evaluation of this threatened and endemic palm, the present author made observations on the gender expression and its polygamo-monoecious nature across all fertile individuals in Kumaon region; some interesting findings were made. Results of this survey are presented in this communication.

The plants produce 1–4 flowering spadices (Figure 1 *f*) during April–May. Each spadix is 0.6–1.2 m long, fleshy green, 3–4 times branched into ultimate panicles and covered by thick spathe at each node, spathe spathulate or awl-shaped, basal largest and completely encircles the node, upper gradually reduced into a bract, densely covered by thick ferruginous tomentum on the outer side, inner side smooth and shining. The flowers grow on ultimate branches of panicles (Figure 1 *g*) in groups of 2–4 or rarely solitary, on the small expanded base. The structure of flower is typically palm-type[10,22]. Flowers are small, more or less regular, cyclic, trimerous, shortly stalked or sub-sessile, perianth in two whorls, both whorls dissimilar with distinct three sepals and three petals, six stamens and three carpels. The flowers exhibit functional dimorphism, i.e. male flowers with functional six stamens and three rudimentary carpels (pistillodes) and female flowers with three ovaries with expanded functional ovules and six rudimentary stamens (staminodes). Both the flowers are similar in colour and structure, except that the female flowers seem to be robust, globose, thick and compact at base due to the expended ovaries and become sessile. The sterile anther lobes are expanded balloon-like when young and sunken on maturity. They never open and anther filaments are small in comparison to the filaments of the functional male flowers. However, the male flowers seem

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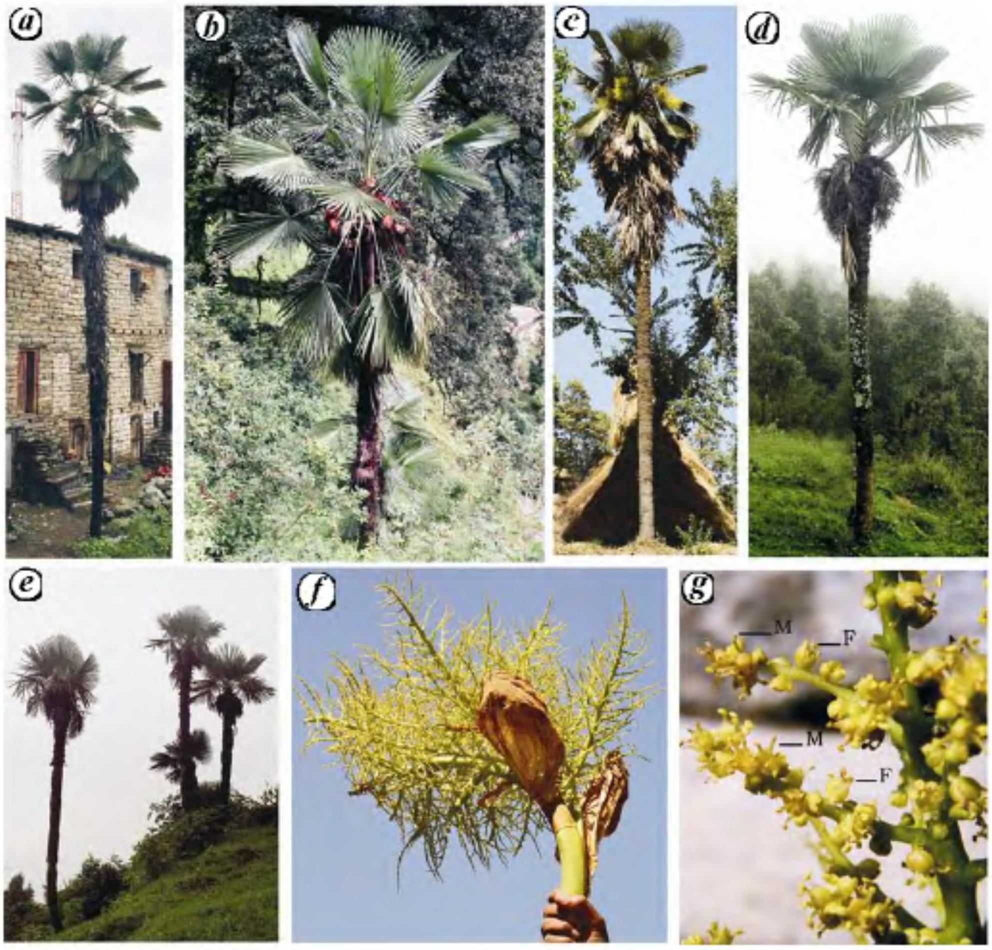

Figure 1. ***a***, Munshyari plant (A); ***b***, Gini plant (B), ***c***, Barabe plant (C), ***d***, Lower lamgarah plant (D), ***e***, Upper lamgarah plants – plants E–G from left to right or from base to top of figure, ***f***, Spadix and ***g***, Flowering panicle showing male and female flowers. Flowers growing at the tip are males with long anther filaments, while flowers growing at the basal portion are females with short anther filaments and sterile anthers.

to be sub-sessile, not thickened at the base due to thin rudimentary, papyraceous pistillodes, somewhat more open and expanded with longer anther filaments. The anther lobes are full with pollen grains, versatile, open by longitudinal slit and completely inverted on dehiscence. Though 2–4 flowers develop in an ultimate expanded base of the panicle, most of them fall. It is also noted that mostly female flowers are solitary and male flowers are in groups.

All the seven identified fertile plants were marked as A, B, C, D, E, F and G respectively (Table 1; Figure 1) and monitored for a period of four years (2004–07). Individual plants with known sexuality (through interview with local people and nature of spadix) were marked for subsequent observations. Initially, during 2004–05 the plants were visited once a year during the fruiting period to observe their gender according to the earlier male–female concept (earlier it was considered that fruit-bearing plants are female, while plants with dried spadices in the late season are male). It was also noted that plant A (at Munshyari) was completely isolated from the nearest flowering plant B (at Gini) by more than 30 km, and on a different aspect of the Kalamuni ridge. Similarly, plant C (at Barabe) was also isolated from the nearest flowering plants D–G (at Lamgarah) by about 4 km, and there was little chance of pollination between C and D–G due to a small mountain barrier. But enquiries about these isolated plants (A and C) revealed that they flower almost every year and produce seeds regularly, and it was presumed that the seeds produced by these two plants may be the result of seed apomixes. However, in 2005 dried spadix and few dried panicles were also noticed between the fruit panicles in these fruit-bearing plants. Furthermore, on enquiring about the flowering and fruiting of plants D–G, it was found that generally they flower every year; however, different plants produced fruits in different years. This irregular seed production in plants D–G and regular fruit setting in isolated plants A and C compelled the present author to make further investigations. During 2006–07, parts of flowering panicles of all identified fertile plants were collected from almost all spadices and

Table 1. Details of *Trachycarpus takil* fertile plants and their flowering and fruiting in Pithoragarh

Plant ID	Approximate height of plant (ft)	Locality and altitude	Approx. distance from nearest fertile plant	Enquiry from local people on flowering and fruiting in previous years	2004	2005	2006	2007
A	± 38	Munshyari Town, Ex. (30°5′N–80°12′E, 2200 m)	30 km from B	Flowers and set fruits almost every year	FL FNC FS	FL FNC FS	FL SPF, SPFM FS	FL SPF, SPFM FS
B	± 14	Gini forest, Ex. (30°2′N–80°11′E, 2100–2500 m).	30 km from A	No data collected (wild plant)	FL FNC FNS	FL FNC FNS	FL SPM FNS	FL SPM FNS
C	± 36	Barabe, Ex. (29°3′N–80°13′E, 1700 m)	4–5 km from plants D–G	Flowers and set fruits every year	FL FNC FS	FL FNC FS	FL SPF FNS	FL SPF, SPFM, SPFMM FS
D	± 20	Lamgarah, Ex. (29°3′N–80°11′E, 2400 m)	Up to10 m from E–G	Flowers and sometimes fruits, sometimes not set fruits	FL FNC FS	FL FNC FS	FL SPM, SPF, SPMF FS	FL SPM, SPF, SPMF FS
E	± 20	Lamgarah, Ex. (29°3′N–80°11′E, 2400 m)	Up to 10 m from E–G	Flowers and sometime fruits sometime not set fruits	FL FNC FNS	NFL – –	FL SPM, SPF FS	NFL – –
F	± 16	Lamgarah, Ex. (29°3′N–80°11′E, 2400 m)	0 m from G and H	Probably flowers and sometimes set fruits	FL FNC FS	NFL – –	FL SPM, SPF FS	FL SPM FNS
G	± 12	Lamgarah, Ex. (29°3′N–80°11′E, 2400 m)	0 m from E and F	Flowering never seen (young plant)	FL FNC FNS	FL FNC FNS	FL SPM FNS	FL SPM FNS

*Ex, Exposed; FL, Flowered; FNC, Flowers not collected; NFL, Not flowered; SPF, Spadices of only female flowers; SPFM, Spadices of mainly female flowers with few male flowers; SPM, Spadices of only male flowers; SPMF, Spadices of mainly male flowers with few female flowers; SPFMM, Spadices of female flowers with female flowers modified into male flower; FS, Fruit set; FNS, Fruit not set.

examined with the help of magnifying lens and microscope. The spadices were again observed in the late season for fruits or dried spadices.

Results of observations on flowering and fruiting are given in Table 1, along with data on locality, height of plant, distance from nearest flowering plant, etc. From the table it is clear that almost all plants flowered every year, except E and F, which are irregular in flowering. The youngest/smallest plants (B and G) produced spadices of only male flowers and never produced seeds; however, other plants produced more than one type of spadice. Plants A and D set fruits in all years during the study period. On examining the flower in 2006–07, it was found that the expression of gender in these plants was unstable, and five different types of flowering spadices, viz. spadices with only male flowers (SPM), spadices with only female flowers (SPF), spadices with mainly female flowers with few male flowers (SPFM), spadices with mainly male flowers with few female flowers (SPMF), and spadices with female flowers in which few female flowers modified into male flowers (SPFMM) were observed in these seven plants.

In 2006, the oldest and largest plants A and C (earlier called females), flowered. Plant A produced SPF and SPFM, and fruits were laden in these infructescences in the late season. In the same year, plant C produced only SPF and fruits were not developed, though all the nearest plants (D–G) were in bloom. In 2007, plants A and C also produced SPF and SPFM, and fruits set on them. Careful observation of plant C in April 2007, showed that most of the flowers growing in a cluster were morphologically similar when young, but soon one flower acted as functional female and became solitary by falling. However, most of the male flowers remained in clusters of 2–4 or sometimes more (Figure 1 *g*). In the middle of May, a large number of unfertilized, female flowers and male flowers were shed and formed a thick bed under the tree. It was also noted that on the same spadix or panicle male flower matured before the female flower. The most interesting phenomenon noted on the same plant was the development of SPFMM after the falling of the male flowers. In this few female flowers were modified into functional males by producing pollens on staminodes. In these modified flowers, out of six stamens, only 1–4 were found with few pollens. The anther filaments of these modified flowers were as long as the anther filaments of pure, functional male flowers. Probably these flowers are basically pistillate, but they have changed their functional behaviour from female to male to ensure pollination. However, it is not clear why these modified flowers had not developed in 2006 in this plant. During 2006, the present author cut one complete spadix for observation and as a herbarium specimen at the first node, but the stump of the spadix developed few small-flowered panicles in the next season (2007), though the remaining three spadices completely dried up in the late season. The sprouting of new panicles in the amputated base may be due to the sexual potential of the plant.

In 2006 and 2007, plant D produced SPF, SPM and SPMF, and both dried fruitless and infructescenses with dried panicles in the late season were noted. Plants E and F produced both SPM and SPF in 2006 and set fruit. However, in 2007, plant E did not flower, and plant F produced only SPM and fruits were not set. However, in the previous year (2005) these plants had not flowered, and in 2004 only plant F flowered and set fruit. SPFMM were not seen in this locality. The fruit output was less in these plants compared to plants A and C. This may be due to the smaller size and production of a large number of male flowers.

From the above observations it is clear that the species reproduces sexually and the seeds produced by isolated plants A and C are by selfing or inbreeding (not asexually or by seed apomixes). This is proved by the drying of female spadices in 2006 and setting of fruits in 2007 in plant C. Thus, *T. takil* is neither strictly dioecious nor strictly monoecious. Most of the young plants behave as male (plants B and G and the type specimen described by Beccari in his garden at Florence, Italy). On ageing, these plants have the capacity to produce fruits also (plants E and F). The largest and oldest plants (A and C) which generally produce seeds, were earlier considered as female, but are actually not perfect females; they bear mostly SPF with few SPFM as well as having the capacity to modify the sterile staminodes into fertile pollen-bearing stamens. The pattern of gender expression in middle-aged plants (E and F) is dubious. Out of the four terms mentioned for genus *Trachycarpus*[21–27], polygamously monoecio-dioecious (with both imperfect and perfect flowers on the same individual as well as male and female flowers on both the same and different plants) is best suited for *T. takil*.

The plants have greater tendencies to behave as unisexual by producing functionally male or functionally female, imperfect flowers. Development of male and female flowers on separate plants or on separate spadices in which male flowers mature earlier than females, shows that basically the species is evolutionarily at the superior stage and planned to outbreed for retaining heterozygosity which protects it from inbreeding depressions caused by homozygosity. But at present most of the fertile plants are isolated and selfing in these plants may be to ensure sexual reproduction for survival of the species. The seed output of plants A and C was less compared to mature *T. fortunei* from Nianital (±1 kg per fructescense or 4–6 kg per plant). Only 700–800 seeds were collected in October 2005 from plant C. Though the embryo is clearly visible in TS, the germination percentage was less (15–20% at Pithoragarh). However, germination percentage of *T. fortunei* from Nainital was high (+90 at Botanic Garden of Indian Republic Noida; unpublished data of the author). The seeds are dispersed by birds and the nearby climate is conducive for germination, but none of the seedlings were noticed growing within 2–3 km area of these isolated mother plants A and C (except one young plant found growing under plant C at Barabe). This poor rate of germination in plants A and C may be probably due to hard seed coat or any other mechanism like selfing or inbreeding depression, including the absence of specific seed-dispersing agents. The fruit set in plants D–F may be the result of both self- and cross-pollination. The large seed output along with small saplings of different sizes (1–5-leaved) growing in the west-facing slope under large oak, *Rhododendron* and *Taxus* trees on a nearby mountain ridge (near Thalkedar temple and in the forest of Bhilont village), is probably due to climatic factors and cross-breeding. These plants grow on the mountain tops where chances of wind and insect pollination is higher and they can also be easily visited by seed-dispersing birds.

The functional behaviour and tendency of young plants (B and G) as male, middle-aged plants as both male and female (D–F) and old-aged plants as female (C in 2006) show that unlike many other angiosperms[28–34]. This plant also has the power of sex reversal from maleness to femaleness along with the age or size of the plant, which is also uncommon in many gymnosperms[35,36] and angiosperms[37–39] due to several factors.

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ACKNOWLEDGEMENTS. I thank Mr Kamal Bhakuni, Govt P. G. College, Pithoragarh for help in the field. Dr M. Sanjappa, Director, Botanical Survey of India, Kolkata and Dr M. Ahmadullah, Botanic Garden of Indian Republic, Noida are acknowledged for providing support and facilities.

Received 27 February 2008; revised accepted 23 October 2008

Water repellency of soils in the lower Himalayan regions of India: impact of land use

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Although soils are generally considered to wet readily, some are actually water-repellent at the surface. This communication presents the recent progress in relating the severity of water repellency to different soil management practices and land uses under the lower Himalayan region of India. All soils under sal forest, chrysopogon and cropland had less water drop penetration time (<5 s) and therefore were classified as wettable. However soils under eucalyptus plantation and panicum stand showed considerable hydrophobicity. This is considered as being caused by differences in organic matter composition rather than amount of organic carbon. If planted indiscriminately and particularly where there is significant competition for land area, nutrients or water, notable problems can occur under the eucalyptus stand.

Keywords: Environmental implications, land use, soil hydrophobicity, soil infiltration rate, water repellency.

ALTHOUGH soils are generally considered to wet readily under rainfall or irrigation, some soils exhibit a reduced, or no affinity to water (water repellency) at the surface and within the root zone. This phenomenon occurs at low to moderate moisture content and has been reported from soils under a range of vegetation types and from many regions around the globe[1]. Water repellency in soils can have serious environmental implications, including reduced seed germination and plant growth as well as irrigation efficiency, accelerated soil erosion and enhanced leaching of agrochemicals through preferential flow[2–5]. Soils containing a large amount of hydrophobic materials (such as plant litter, residue and microbial by-products) may become water-repellent or less wettable[6,7]. These are generally thought to be present as a coating on soil particles or aggregates[8]. The accumulation of hydrophobic waxes on soil particles[9], humic and/or fulvic acid soil coatings[10] and other long-chained organic compounds on or between soil particles[11,12] are all accepted as factors contributing to this negative-impact phenomenon. Soil water repellency often leads to severe run-off and erosion, rapid leaching of surface-applied agrochemicals and loss of water and nutrient availability for crops. The degree of repellency and wettability is traditionally judged using the water-solid contact angle (γ). A solid is classified as being water-repellent if $\gamma > 90°$ and water wettable if

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