Stylar movement in *Valeriana wallichii* DC. – a contrivance for reproductive assurance and species survival

Enclosure of ovules in a closed ovary and development of a pistil with well-defined stigma and style mark some important evolutionary achievements in the reproductive cycle of angiosperms. In most of the cases stigma, as the uppermost portion of pistil, is the seat of pollen reception[1]. Style as the most elongated part of the pistil keeps the stigma properly placed and positioned so that pollination gets affected either unassisted or through biotic or abiotic agents[1]. Being the path of the pollen tube, the style is generally straight and immobile. However, in certain species of angiosperms, styles do exhibit curvature movements either to promote outcrossing[2,3] or to effect selfing or to achieve delayed selfing[4–6]. All these provide for reproductive assurance[7].

During our studies on *Valeriana wallichii* DC., an important medicinal plant of India, we discovered an interesting mechanism in the flowers of the species. Styles of these flowers were seen showing movements by either forming a sharp bend above half of their length or by assuming a bow shape or by slightly tilting towards one of the anthers of the same or the adjacent flower in a complex biparous cyme (Figure 1 *a*), to affect the pollination and thus to assure fruit and seed set.

V. wallichii DC. belongs to the family Valerianaceae and is a prized medicinal plant of India. The species is widely distributed from Kashmir in the northeast to Bhutan in the east up to 3000 m (ref. 8). The species is exploited for its rhizome, which is the source of the active principle – valepotriates, for which the plant is sought after[9]. The plant propagates vegetatively by underground rhizome and sexually by producing a large number of seeds. Sexual reproduction extends over a period of 6–7 months from December to May in Rajouri, where the studies were made. The peak blooming period is between January and March. During this period the temperature of the area fluctuates between 5.6°C and 26.8°C. The plant is a prolific flower producer. The number of flowers produced by a plant varies from 130 to 633 ($X = 330 \pm 119$). Flowers are bracteate, epigynous, hermaphrodite with a white corolla which is companulate with five spreading lobes (Figure 1 *b*). The calyx is located at the distal end of the inferior ovary and is represented by hook-like structures which transform into feathery pappus in fruits. Average size of flowers is 6×5.7 mm. Androecium comprises of three epipetalous stamens. Gynoecium comprises of a tricarpellary syncarpous inferior ovary, a long style arising from the top of the ovary and a terminal, trifid dry and papillate stigma. Anthesis begins at 05:45 h in

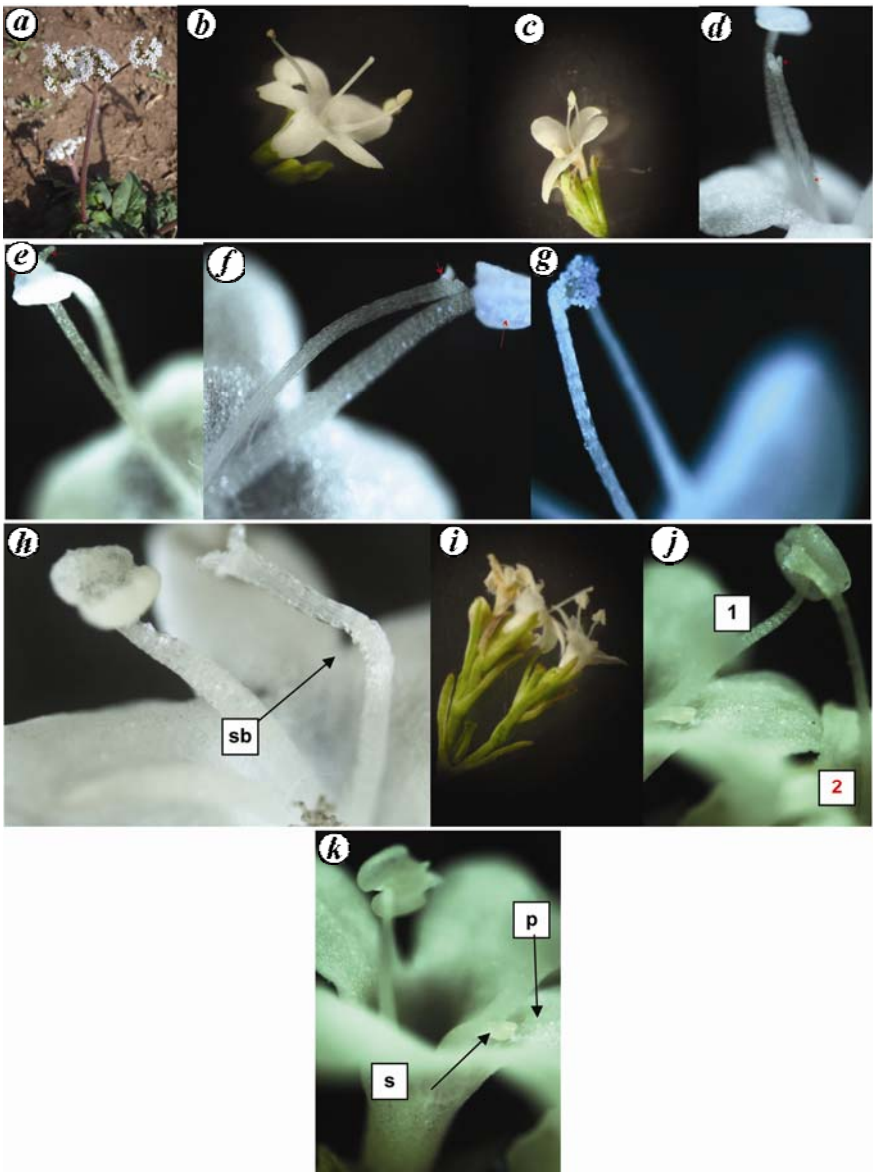

Figure 1. ***a***, A compound biparous cyme of *Valeriana wallichii* DC.; ***b***, Flower with a straight style away from three stamens (× 5); ***c***–***k***, Stylar movement and bending. ***c***, Style reached up to the level of anther and stigma attached with dehisced anther (× 4); ***d***, Style deflexed towards staminal filament (× 5); ***e***, Bilobed receptive stigma attached to the anther (× 5); ***f***, Styles forming a bow shape to reach up to anther (× 7); ***g***, Bow-shaped style at the level of anther (× 7); ***h***, Style forming a bend towards the dehisced anther (× 7); ***i***, ***j***, Style from one flower touching the anther of a neighbouring flower in the group (× 2 and × 7); ***k***, Style tilted towards the corolla lobe and stigma touching pollen on corolla (× 11). sb, Style bent at 90°; p, Pollen on corolla; s, Stigma trapping pollen from corolla; 1, Stamen of one flower, and 2, Style of the second flower.

Table 1. Experimental manipulation for checking style bending

Manipulation	Number of flowers manipulated	Number of flowers showing stylar movement
Emasculation	123	13
Manual pollination with self pollen	46	3
Bagged	885	546

the morning and continues throughout the day. Flowers in a plant exhibit asynchronous blooming; these are protandrous and anther dehiscence, and stigma receptivity are temporally separated by about 30 h. Pollen grains are sticky and pollination is affected by insects belonging to orders Hymenoptera and Diptera. These insects visit flowers in large numbers for pollen and nectar, and disperse the pollen from anthers before the stigma becomes available for self-pollination. Because of strong protandry, asynchronous blooming and close aggregation, the flowers practice mixed pollination during the peak flowering period. The species is self and cross-compatible. This was confirmed by manual pollination experiments in which manually self and manually cross-pollinated flowers yielded 72.5% and 77.3% fruit set respectively, compared to 65% in open pollination. As the blooming season proceeds (January–March), atmospheric temperature rises and many other angiosperms surrounding this species start blooming. Many of these bear bright-coloured flowers. Consequently, insect visitation rate to *V. wallichii* flowers is reduced considerably. In spite of the fact that flowers of *V. wallichii* continue producing sufficient pollen and receptive stigmas are still available, pollination fails due to non-availability of pollinators. This induces a special mechanism in the style to trap self pollen grains that remain adhered to the anthers. During this time, the styles showed movement (Figure 1 *c*–*k*). In many flowers, unpollinated styles were seen moving towards the anther of the same (Figure 1 *c*–*h*) or a neighbouring flower (Figure 1 *i* and *j*), wherever pollen grains were present. The styles either become deflexed towards staminal filament and grew along with it (Figure 1 *d*) or formed a bow-shape (Figure 1 *e*–*g*) or a sharp bend above half of their length (Figure 1 *h*). Sometimes the style was seen to bend towards the corolla lobe to trap the pollen fallen on its surface during dehiscence. The stigma thus trap pollen this way and gets pollinated (Figure 1 *k*). This strategy of the style to ensure pollination and reproduction was checked experimentally. For this phenomenon, 1714 unbagged flowers in 69 plants were checked. Of these, 448 flowers exhibited style bending (35%). Six inflorescences were bagged in six plants having 885 flowers to check the bending. In 546 flowers (61.6%), the style was bent (Table 1). Results of bagging experiments showed that frequency of bent styles in bagged inflorescences was more than that in open flowers. In emasculated flowers, it was observed that in most cases the style remained straight and curvature, if any, was towards the anther of the neighbouring flower. Bagged flowers produced fruit up to the extent of 35%, indicating that stylar movement is an adaptation to assure reproduction in *V. wallichii*, and this special mechanism is induced due to lack of insect visits. In the context of stylar behaviour, it has been recorded that this mechanism is not being operated to delay selfing or to promote outcrossing. Nevertheless, the plant has adapted the strategy to assure reproduction and survival in case pollination fails. This speaks of the novelty of the species to become self-sustained under conditions limiting reproduction.

1. Verma, S., Kaul, V., Magotra, R. and Koul, A. K., *Curr. Sci*., 2008, **94**, 1372–1374.
2. Verma, S., Magotra, R. and Koul, A. K., *Curr. Sci*., 2004, **87**, 207–215.
3. Li, Q., Xu, Z., Kress, W. J., Zhang, L., Deng, X., Gao, J. and Bai, Z., *Nature*, 2001, **410**, 432.
4. Raun, C. J., Mopper, S., Teixeira da Silva, J. A., Qin, P., Zhang, Q. X. and Shan, Y., *Plant Syst. Evol*., 2009, **277**, 207–215.
5. Sun, S., Gao, J. Y., Liao, W. J., Li, Q. J. and Zhang, D. Y., *Ann. Bot*., 2007, **99**, 660–661.
6. Liu, K. W., Liu, Z. J., Huang, L. Q., Chen, J. and Tang, G. D., *Nature*, 2001, **441**, 945–946.
7. Jain, S. K., *Annu. Rev. Ecol. Syst*., 1976, **7**, 469–495.
8. Hooker, J. D., *Flora of British India*, L. Reeve and Co Ltd, England, 1897.
9. Mathur, J. and Ahuja, P. S., *Plant Cell Rep*., 1991, **9**, 523–526.

ACKNOWLEDGEMENTS. We thank the Department of Biotechnology, Government of India for funds. We also thank Prof. A. K. Koul, Dean, SBB, BGSBU for guidance. Dr Namrata Sharma, Department of Botany, University of Jammu, provided valuable inputs during the course of this work.

Received 27 December 2010; revised accepted 16 March 2011

ANKUSH KHAJURIA
SUSHEEL VERMA*
PUNEET SHARMA

Conservation and Molecular Biology Lab,
Centre for Biodiversity Studies,
School of Biosciences and Biotechnology,
Baba Ghulam Shah Badshah University,
Rajouri 185 131, India
**For correspondence.*
e-mail: eremurus@rediffmail.com