White egret orchid evolved frilly petal to support pollinator hawkmoth

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Figure 1: The white egret orchid (Habenaria radiata) resembles a dancing white egret. Credit: Kobe University

The wild orchid Habenaria radiata's pure white petals resemble a white egret in flight (hence its common name white egret orchid). H. radiata has been loved by people since ancient times but the adaptive significance of the flower's characteristic jagged shape has been unclear until now. A multi-institutional research group has been working for three years to solve this mystery by conducting field experiments in which the feather-like fringe was removed, and detailed behavioral observations of the orchid's pollinators.

The research collaboration consisted of Associate Professor Suetsugu Kenji and student Abe Yusuke (who completed his Master's degree in the 2021 academic year) of Kobe University Graduate School of Science, Asai Takeshi and Matsumoto Shuji of Himeji Tegarayama Botanical Garden, and Hasegawa Masahiro of Osaka Museum of Natural History.

From the results, they discovered that in their natural habitat, white egret orchids with the fringe removed produced fewer healthy seeds per individual fruit than intact plants. Hawkmoths, which are major pollinators of this orchid, normally grasp onto the fringe with their mid-legs to steady themselves when they drink its nectar, however the researchers observed that the hawkmoth was often unable to do this on plants with the fringe removed. In other words, this fringe functions as a supportive platform for the pollen-carrying hawkmoth. It was previously thought that hawkmoths mainly hover while drinking nectar.

Although the white egret orchid utilizes hawkmoths to transport its pollen, these important findings indicate that the eye-catching fringe is more than a visual aid for pollinators, and has evolved to support the hawkmoth while it feeds on the nectar.

These research results were published online in the international journal *Ecology* on June 21, 2022.

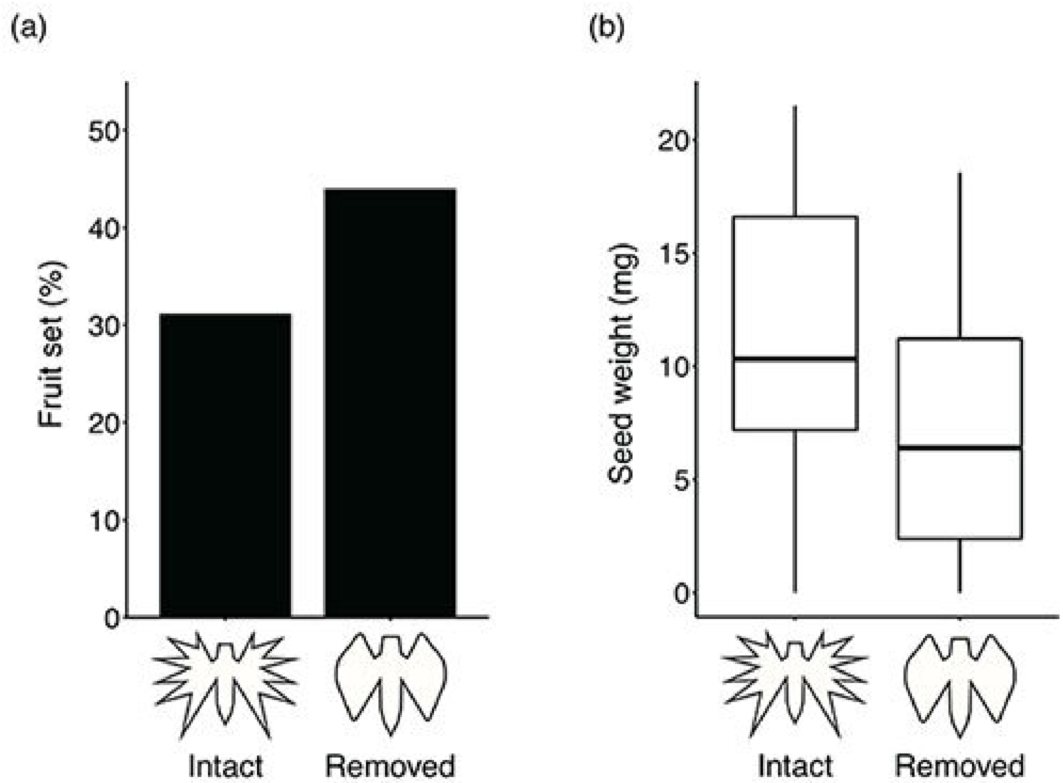

Figure 2: Results of removing the fringe from white egret orchids in a natural environment. Contrary to expectations, only the number of healthy seeds per fruit decreased; there was no reduction in the flower's rate of fruit production (an indicator of the frequency of pollinator visits). Credit: Kobe University

Research background

Around 90% of flowering plants (angiosperms) rely on animals such as bees to help them pollinate; when the insect transports pollen between flowers, it receives a reward (nectar etc.). It is known that mutualisms with pollinators also play a significant role in flower shape diversity. Numerous orchid species in particular have evolved dramatically shaped flowers; this is noticeable even if you look at the orchids found in florist's, such as the moth orchid (Phalaenopsis aphrodite).

Orchids have three petals, one of which is large and stands out, and it is thought that this petal formation evolved alongside the insects that transport its pollen. In fact, many orchid species utilize particular kinds of insects as pollinators and it is thought that the variations in dramatic petal structure result from each species of orchid evolving to appeal to specific insect species.

The wetland-growing wild white egret orchid is no exception: it has evolved intricate petals. Its beautiful appearance calls to mind a white egret soaring through the sky and has been a familiar plant in gardens for hundreds of years (Figure 1).

However, until recently it was unclear what kind of mutualism with pollinators had led the white egret orchid's fringed petal to evolve into such a distinctive shape.

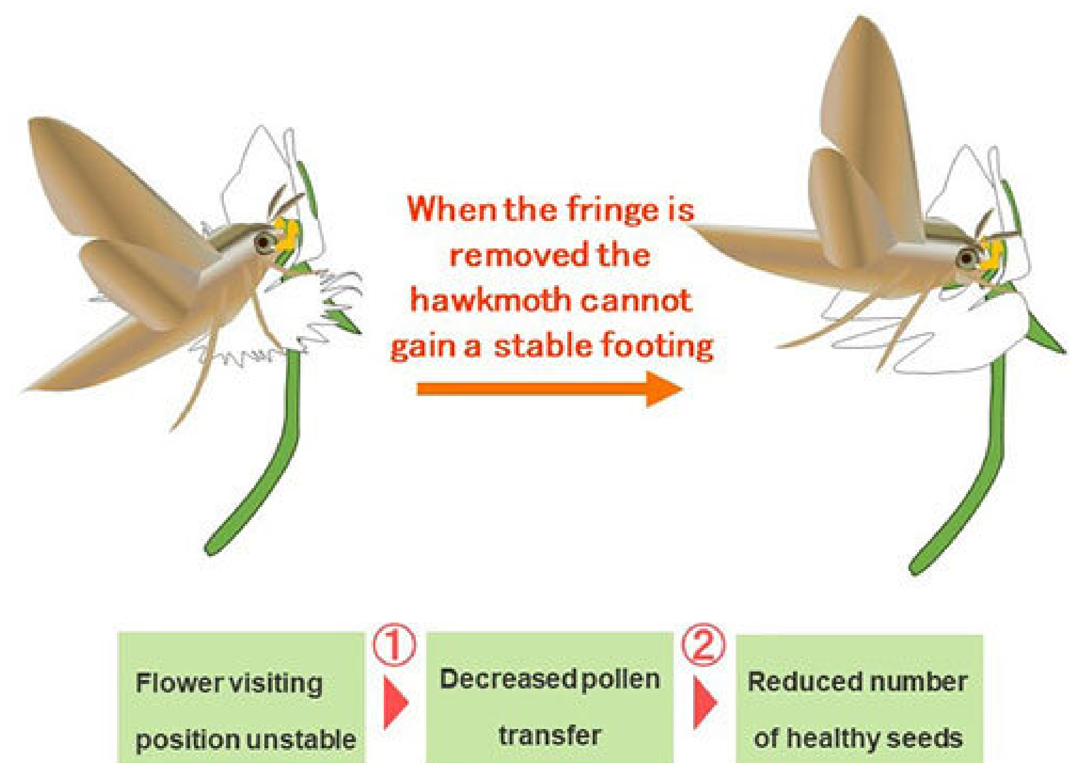

Figure 3: The adaptive significance of the white egret orchid's fringe as proposed by this study. Based on the results of the fringe removal experiment in natural populations and the detailed observations of pollinator (hawkmoth) behavior.

In order to discover the extent to which petal fringe shape contributes to the white egret orchid's reproductive success, the researchers conducted a fringe removal experiment in a natural setting. In general, it is thought that petals mainly function as a visual attractant. Hawkmoths, the primary pollinators of the white egret orchid, tend to hover in the air while drinking nectar from flowers and so do not require a place to rest their legs while feeding. Consequently, the researchers hypothesized that the major function of the fringe is to attract the hawkmoth visually.

Even though the hawkmoth is nocturnal, it can rely on its vision to some extent to recognize flowers, thus big flowers with a fringe appeal to it. For this reason, the flowers of other plants (such as snake gourd) pollinated by hawkmoths often have deeply divided fringed petals. Therefore, it is thought that fringed flowers have adapted to effectively attract hawkmoths (who prefer flowers with big fringes) because flowers with a fringe can conserve more resources than fringeless flowers of the same diameter.

If the fringe functions as a visual attractant, it can be predicted that specimens with the fringe removed would have a reduced fruit production rate as fruit production is an indicator of the frequency of pollinator visits. However, this study showed that, contrary to this prediction, there was no decline in fruit production in specimens with the fringe removed (Figure 2). In other words, the fringe did not play a significant role in attracting hawkmoths to the white egret orchid's flower. However, flowers with the fringe removed had a lower rate of healthy seeds in their fruits when compared to those with the fringe intact. Furthermore, artificially pollenated white egret orchids produced the same rate of healthy seeds regardless of whether or not they had a fringe. This demonstrates that the cause of the reduced seed production in fringeless specimens is related to the flower's mutualism with its pollinators, not due to damage incurred when the fringe was removed.

To investigate how this reduction in the number of healthy seeds was related to the pollinator behavior, the researchers conducted detailed behavioral observations of hawkmoths. These results revealed that this major pollinator of white egret orchids did not hover continuously while drinking nectar but instead grasped onto the petal fringe with its midlegs. However, with the fringe removed, the hawkmoth could not grasp onto the petal in many cases. Therefore, it is highly possible that without the stability provided by the fringe, the hawkmoth could not pass on as much pollen to the plant, thus resulting in fringeless plants receiving fewer pollen grains per visit and producing fewer healthy seeds (Figure 3).

Up until now, research into the function of petals has focused on their role in visually attracting pollinators and other functions beyond this have received little attention. In particular, the results of this study have indicated that contrary to the researchers' hypothesis, the eye-catching fringe plays more of a role as a foothold while feeding for hawkmoths (that were believed to hover while drinking nectar) than as a visual attractant.

"The white egret orchid was given its name because its brilliant white petals resemble the bird in flight. According to legend, the soul of a white egret that died was reborn as the much-loved white egret orchid. Nevertheless, it is now evident that fringes primarily stabilize the hawkmoth (the primary pollinator)'s posture, increasing pollen transfer. I am pleased that we have revealed the unexpected adaptive significance that is at the heart of its distinctive fringe," Professor Suetsugu comments.

More information: Kenji Suetsugu et al, Specialized petal with conspicuously fringed margin influences reproductive success in Habenaria radiata (Orchidaceae), *Ecology* (2022). DOI: 10.1002/ecy.3781

Provided by Kobe University

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