Predicting pollen capture efficiency helps grow larger kiwifruit in New Zealand’s most important horticultural export.

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Kiwifruit is the most important horticultural export from New Zealand, with crop value relying heavily on the size of the fruit to sell at premium prices in international markets. Growers recognize that the single limiting factor for a good-sized fruit is the number of pollen grains fertilizing its flower. Sufficient fertilization must be completed in the annual eight-day flowering period, when the flowers are receptive. Often bees are used to transfer pollen from male flowers to female flowers, but bees are unreliable. Wind also assists in this transfer, but this natural pollination is found by growers to be insufficient for commercial purposes.

Growers can now blow pre-collected pollen onto kiwifruit flowers with an air jet and choose the time for optimal flowering. However, before this study, no one had measured or estimated the pollen capture efficiency by kiwifruit flowers from airflow. CFX-5, incorporating particle trajectories (calculated using the Lagrangian framework) around a full-scale rigid flower, has provided a sound prediction of the efficiency of pollen capture onto the critical area for fertilization —
Front and side views of a full-open female kiwifruit flower (cv Hayward). More than 200 female kiwifruit flowers were photographed and studied to extract the detailed geometry for a model flower in CFX simulations.

A close-up look of the meshed flower model.

(a) Smoke visualization of flow field around a single full-open green kiwifruit flower under a uniform 1.2 ± 0.1 m/s flow from the front in a glass wind tunnel. The CFX simulated flow field is shown in (b). The arrows indicate the flow direction.

the stigma. This prediction is adequate for air velocities below those where petal flutter begins (3 m/s). For example, the predicted pollen collection efficiency indicated that wind pollination alone is insufficient, in agreement with growers’ experience.

The use of CFX has enabled a more fundamental understanding of the capture mechanism of airborne pollen onto the stigma. The predicted flow fields exhibit at least two recirculation regions, a larger recirculation downstream of the flower and some small eddies in the airspace between the stigma and the petals. The spiralling large downstream vortices direct the pollen backwards to the stigma area for a second pollen collection after the first collection by the approaching flow. The eddies near the filament and stigma bushes trap the pollen, increasing their chances of being captured by the stigma. Using the smoke visualization around a real kiwifruit flower in a wind tunnel confirmed the airflow patterns.

This flower model enables the recommendation of optimum ways of spraying pre-collected pollen, which is expensive and sometimes in short supply. This includes the effect of jet direction onto the flower, nozzle-to-flower distance, the diameter of the nozzle and initial jet velocity. Selected CFX simulations were confirmed with experiment and found to be in good agreement. Furthermore, the use of user-Fortran in CFX also allowed the assessment of the enhancement of pollen collection by electrostatically charging the pollen. The results here provide valuable insight for manufacturers to improve operating conditions and improve design of air jet sprayers for effective and economic delivery of pollen onto the flowers.