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Fluid Dynamics of Hydrophilous Pollination in *Ruppia* (widgeon grass)

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Abstract

The aim of this work is to understand the physics underlying the mechanisms of two-dimensional aquatic pollen dispersal known as hydrophily. We observed two mechanisms by which the pollen released from male inflorescences of *Ruppia* is adsorbed on a water surface. Adsorbed pollen masses then combined under the action of capillary forces to form pollen rafts. This increases the probability of pollination since the capillary force on a pollen raft toward a stigma positioned at the water surface is much larger than on a single pollen grain.

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Keywords: Hydrophily; pollination; *Ruppia Maritima*; surface tension; capillary forces

1. Introduction

Ruppia maritima is a type of seagrass in which the transport of pollen from an anther to a stigma takes place primarily on a water surface [1-3], and so the pollination process can be called two-dimensional (see Fig. 1). Since the density of pollen grains is larger than that of water, a mechanism is needed for transporting them to the water surface where they become trapped at the air-water interface. If they are not adsorbed on the water surface they quickly sediment away from stigmas which are generally present at or near the water surface. In fact, to facilitate pollination, matured stigmas position themselves so that they are at the water surface during low tides (see Fig. 1b). The aim of this article is to model the fluid dynamic mechanisms by which the pollen grains from an anther are adsorbed in the water surface and the hydrodynamic forces that govern their subsequent motion in the surface toward a stigma.

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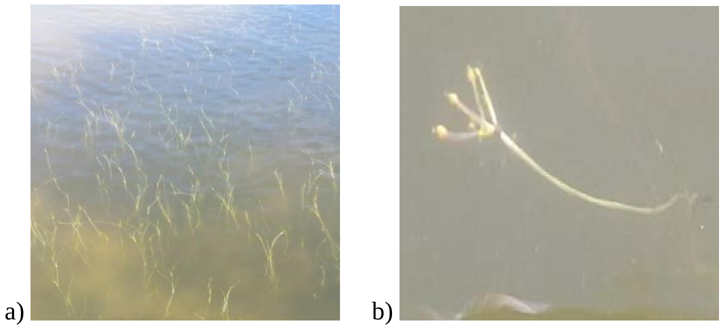

Fig. 1. (a) *Ruppia maritima* in a lagoon at the Jersey Shore. The photograph was taken during low tide. (b) Stigmas floating at the water surface.

An anther can release its pollen either below or above the water surface depending on its position relative to the water surface, and, in some cases, it can release the pollen right at the surface when it is in contact with the water surface. Before they are released from the anther the pollen grains are clumped together in a kidney-shaped mass. When the mass comes in contact with the water surface the contained pollen partially disperses on the surface. The dispersion occurs in two-dimensions, i.e., on the water surface, in the sense that a significant fraction of the pollen grains are adsorbed at the surface. The pollen grains that are not adsorbed at the surface sediment to the bottom as they are denser than water. Pollen dispersion on the surface is a crucial first step in the formation of floating porous pollen structures called "pollen rafts." It is well known that particles trapped in liquid surfaces interact with each other via lateral capillary forces which arise because of their weight to form clusters or monolayer arrangements [4-6]. A common example of capillarity-driven self-assembly is the clustering of breakfast-cereal flakes floating on the surface of milk. The deformation of the interface by the flakes gives rise to lateral capillary forces that causes them to cluster. This is the mechanism by which pollen particles cluster together to form pollen rafts.

Pollen clusters and rafts adsorbed in a water surface are subjected to flow-induced hydrodynamic forces and capillary forces. The vertical component of capillary force keeps them afloat, and the lateral component moves them tangentially on the water surface towards other clusters and rafts, and towards the stigmas located at the surface.

2. Results

For the last three years, we have collected *Ruppia maritima* from the north coast of Long Island and the Jersey Shore just as it was coming into bloom. Field samples of male and female inflorescences along with the water from the site were collected for experimentation at Brooklyn Botanic Garden and the New Jersey Institute of Technology. The salinity of water was about 22 ppt (parts per thousand). The structure of an anther and the contained pollen is shown in Fig. 2. The size of *Ruppia* pollen grains is about 40 microns, and the density is slightly larger than the density of brackish water.

Under natural conditions, male inflorescences can be above, below or in contact with the water surface, and this may change for an inflorescence as the water level varies during tides. Therefore, in our experiments we placed the male inflorescences in the beakers so that they were a few millimeters above or below the water surface. The roots of the plants were kept immersed in the native water. The pollen travelled to the water surface and was adsorbed at the surface, and subsequently travelled laterally on the surface toward a stigma.