IoT based automatic pollination for vertical farming

INTRODUCTION

Vertical Farming is a practise of growing crops in vertically stacked layers. It is done in a controlled environment where we artificially control the light, temperature, water system and other useful factors.

The modern concept of vertical farming was proposed in 1999 by Dickson Despommier, professor of public and Enviromental Health at Columbia University. He with his students came up with a design that could feed 50,000 people.

The vertically stacked layers of produce can be easily set up in confined locations such as skyscrapers and shipping containers and even in small scales inside apartments. This reduces the dependency on farmlands and allows agriculture to take place at virtually any location.

As per Food and Agriculture Organization of the United Nations, with the global population expected to cross 9 billion by 2050,raising food production by 70% or more would be the need of the hour. In this scenario vertical farming can be idolized as a solution which can manage this ‘food desert’.

If we see the advantages of vertical farming, it helps to meet the challenges of future, it is highly water efficient , it is weather independent and rise is organic crops.

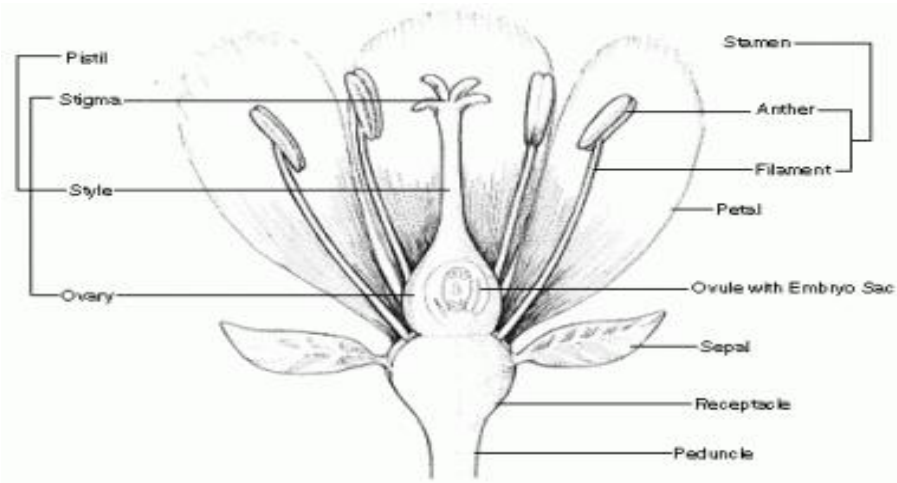
But one of the major disadvantage of vertical farming is lack of pollination which is done in traditional farmig naturally with the help of wind, bees , insects and other factors since it is done in controlled environment. Hence it needs to be done manually which is highly time consuming and labour intensive.

In this paper we have come with an idea of pollinating the crops artificially in these type of controlled environment.

What is Pollination?

The act of transferring pollen grains from male anther of a flower to the female stigma. Once on the stigma , pollen may germinate which means that a pollen tube forms on the sticky surface of the stigma and grows down into the ovule of the plant.

Plants produce offspring by creating seeds. Seeds contain genetic information to produce a new plant. Flower are the tools that plants use to make these seeds. Seeds can only be produced when pollen is transferred between flowers of the same **species**



Types of Pollination:

Self Pollination-

Self-pollinating species can reproduce even if animal pollinators are not present. However, reproduction through self-pollination reduces genetic diversity.

The anther opens and the pollen lands on the stigma of the same flower.

To promote cross-pollination and increase genetic diversity, plants have evolved a wide variety of sexual strategies to attract pollinators and spread pollen from one flower to another of the same species.

Cross Pollination-

Anthers open on one flower and a vector (insects, wind, or animals) moves pollen to the stigma of another flower. Pollinators may visit several flowers on one plant or may visit several flowers of the same species on a few different plants

Some plants have evolved to have self-incompatibility mechanisms to avoid self-pollination. A physiological barrier makes it difficult or impossible for a flower to fertilize itself even though it may have been abundantly pollinated with its own pollen.

METHODOLOGY

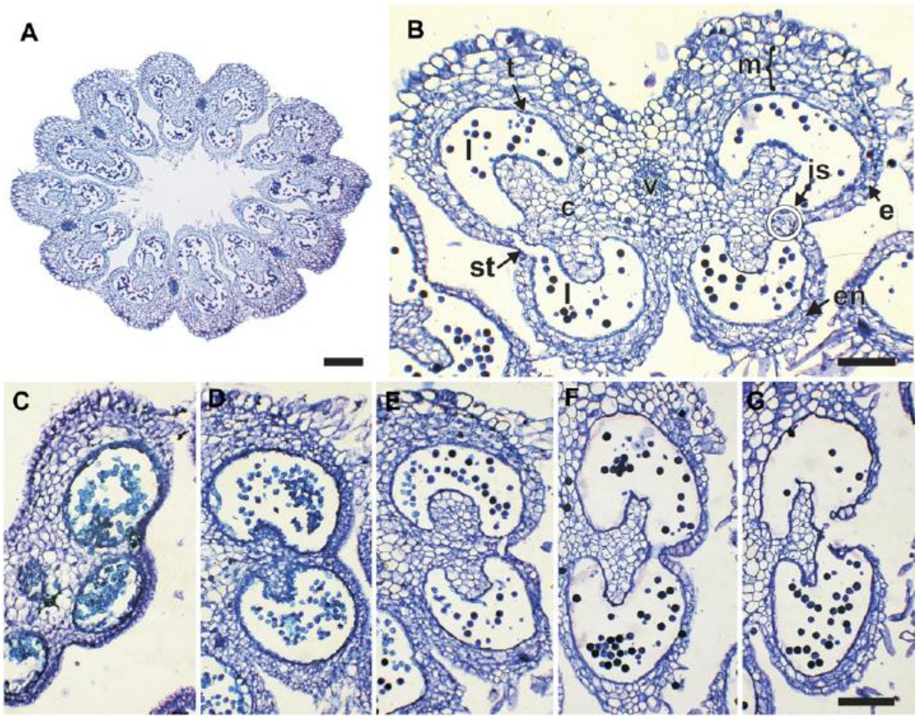
In our work we have considered a single layer as our subject which consists of tomato plant(monoecious) for out IoT based automated pollination. The plants are kept in a temperature greater than 17˚C and less than 34˚C with adequate humidity to ensure better pollination.

Identifying a flower ready for pollination:

Most of the plant species having after buds were opened automatically both the organ should be ready for the fertilization in some case of the plant after pollen anthesis simultaneous stigma have start the receptivity of the stigma surface.The flower that already is ready for fertilization.

Tomatoes are self-pollinating, as flowers are equipped with both male and female parts. One tomato plant is capable of producing a crop of fruit on its own, without the need of planting another one. Nonetheless, nature doesn’t always cooperate. While wind normally

moves the pollen around for these plants, when there is none or when other factors, such as high temperatures and excessive moisture or humidity occur, poor pollination may result.
Living in a controlled environment(in vertical farming) it would be really difficult for these plants to pollinate.



Structure and development of the tomato androecium and anther. A, Whorl of anthers constituting the androecium. Bar = 200 m m. B, Tissues/structures of the anther. c, Connective tissue; e, epidermis; en, endothecium; is, interlocular septum; l, locule; m, middle layer; st, stomium; t, tapetum; v, vasculature. Bar = 100 m m. C to G, Developmental series illustrating the progressive loss of sporophytic cell layers/structures leading up to dehiscence. Tapetal layers apparent at stage 9 (C) and 11 (D) begin to be lost by stage 13 (E), the interlocular septum being close to disruption at that time (E), and loss of the septum is seen by stage 16 (F). There is a progressive loss of cell layers of the connective tissue and the middle layer/endothecium from stage 13 (E) through stage 16 (F) leading to dehiscence (G), with the cells surrounding the stomium separating at stage 20 (G), marking the completion of the dehiscence process. Bar in G = 100 m m. [See online article for color version of this figure.

How do tomato flowers pollinate?

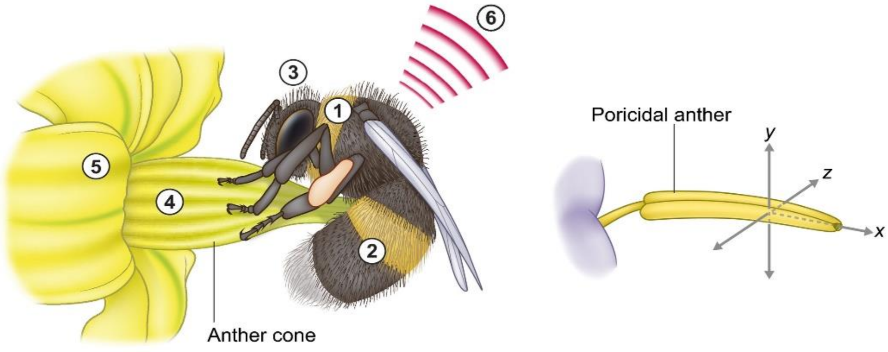
Their poricidal anthers require vibration to impart inertia on the pollen grains within the anther locule so that they can overcome the adhesive forces and exit through the apical pore.

Only specific stimulation can cause this reaction which serves to distinguish so that only the most efficient pollinators can extract pollen. This suggests that vibrational stimulation beyond that capable by insect morphologies may elicit greater pollen expulsion.

Buzz Pollination Mechanism

Buzz pollination is a type of pollination in which bees use vibrations to extract pollen from flowers, incidentally pollinating them. The behaviour of producing vibrations on flowers to collect pollen is sometimes called "sonication" or "buzzing" due to the relatively loud sound associated with the vibrations produced by bees.

Buzz pollination takes its name from the audible component, or 'buzz', that can be heard when a bee vibrates a flower (Macior, **1964**). For this reason, the behaviour in which bees produce vibrations while collecting pollen from flowers is often called sonication (Cardinal *et al*., **2018**). Although, it was previously suggested that pollen release was the result of the combined effects of 'acoustic turbulence' and anther vibrations (DeTar *et al*., **1968**), our current understanding suggests that sound is a by-product of the bee's vibrations, which do not contribute to pollen extraction (Buchmann, **1983**; Cocroft & Rodriguez, **2005**). The vibrations produced by the thoracic muscles are transmitted to the flower via direct physical contact of the bee's body including the head (bees usually bite the anthers while vibrating, Russell *et al*., **2016**), thorax, abdomen, and to a lesser extent the legs (King, **1993**) . Sonication (applying sound to agitate particles), therefore, may be a misleading term when used in the context of pollen extraction, and it may be best to use 'floral vibrations' or 'vibrations on flowers'. In any case, buzz pollination is a vibrational phenomenon characterised by both acoustic and substrate-borne components .



Vibrations produced by a bee visiting a buzz-pollinated flower. Left-hand panel: diagram of a bee vibrating the anther cone (in yellow) of a *Solanum*-like flower with poricidal anthers. Right-hand panel: diagram showing a single poricidal anther (in yellow) and three axes of vibration (*x*, *y*, *z*). The indirect flight muscles cause cyclical deformation of the bee's thorax that results in vibrations (1). These vibrations are transmitted to the anther cone (4) by direct contact with the thorax, head, abdomen and, to a lesser extent, the legs (1–3). Vibrations are also transmitted to other parts of the flower including the petals and sepals (5). The vibrating bee also transfers energy to the surrounding air that results in an audible component (sound; 6). Although this sound is what gives this behaviour its name (that is sonication or buzz pollination), the contribution of the acoustic component to the shaking of the anthers is negligible. Pollen is expelled from the anthers because of the vibrations transmitted from the bee to the anthers. In Buchmann & Hurley's (1978) biophysical model of buzz pollination, the rate of pollen release from the anther is proportional to the velocity with which the anther vibrates along either the *y*- or *z*-axes