MEETING REPORT

Utilization of vertical spaces for horticultural crop production in urban and peri-urban areas*

It is estimated that by the year 2050, the world's population would increase to ten billion, and close to 80% of human settlements would be concentrated in and around urban locations. To feed this urban-centric population, huge tracts of land would be required. But owing to competition from non-agricultural sectors, scientists and planners are sceptical about the availability of such expansive land parcels, especially those around the existing and futuristic urban agglomerations. In this context, well-designed farms that utilize space vertically rather than horizontally, can eliminate the pressure on an already overburdened earth and help create a cleaner environment.

Vertical farming can be considered as an extension of indoor farming that evolved in the 1700s with the advent of greenhouses, with the primary objective of harnessing the off-season crop cultivation potential during unfavourable seasons. Vertical farming facilitates year-round cultivation in multi-storied structures using artificial illumination. Modern greenhouses are constructed using UV-stabilized plastics over a metal framework, where crop production takes place on a soil/cocopeat substrate or substrate-less systems such as hydroponics/aeroponics. Such greenhouses are limited in their production capacities since they are predominantly single-storied and depend to a great extent on natural sunlight, though provisions are made for artificial lighting in the high-end versions. This limitation can be overcome to a great extent by multi-storied, vertical farms that are nourished by hydroponic/aeroponic systems and illuminated by artificial lighting. Most commercial vertical farm ventures operate out of existing warehouses or abandoned factories that have been suitably converted to hydroponic/aeroponic facilities with LED-based illumination systems.

Though vertical farming has been in vogue since ancient times as evidenced by the Hanging Gardens of Babylon, the modern concept of vertical farming involves the union of plant biology and engineering know-how. In the year 2010, an American scientist Dickson Despommier, published a book, *The Vertical Farm: Feeding the World in the 21st Century*, wherein he laid down the principles and practices of modern vertical farming around cities, and inside buildings, instead of horizontal expansion on the ground. As a result, he is widely acknowledged as the 'Father of Vertical Farming'. The advantages of vertical farming as envisioned by Despomier, include: year-round crop production, elimination of agricultural run-off, significant reduction in the use of fossil fuels for operation of farm machines and transport of crops, utilization of abandoned or unused properties, reduction in weather-related crop failures, sustainable food supply for all urban centres, conversion of black and grey-water to drinking water, addition of energy back to the grid via methane generation or plasma arc gasification, creation of new urban employment opportunities, reduction of the risk of infection from agents transmitted at the human–agricultural interface, and return of farmland to nature, thereby helping restore ecosystem functions and services.

Over the last few years, multi-storied vertical farms have been established in Japan, Singapore, Taiwan, China, Korea and the United States of America. Some vertical farms have been constructed by adding on to existing buildings, while few are green field edifices. But this practice is yet to gain momentum in India. Perhaps time is ripe for the country to gear up and introduce this space-saving practice, especially in the urban and peri-urban clusters in order to meet the nutritional needs of a burgeoning population.

In view of its importance, an international conference on vertical farming was organized to serve as a curtain raiser for the introduction of this method of farming with modifications to suit the Indian context. Christine Zimmerman (Chairperson, Association for Vertical Farming, Munich, Germany) welcomed the gathering of scientists from various horticultural institutions, representatives from the industry around the world and practitioners of this system of farming, and introduced the audience to the concept of vertical farming. The conference was inaugurated by S. Ayyappan (Department of Agricultural Research and Education (DARE), and Indian Council of Agricultural Research (ICAR), New Delhi). He presented the overall view of agriculture in 2050 and stressed the need for new technologies like vertical farming, especially with respect to climate change. N. K. Krishna Kumar (ICAR, New Delhi) presented an overview on Indian horticulture. He listed novel technologies that have contributed to an increase in productivity of Indian horticulture by leaps and bounds. He also advocated the need for urban and peri-urban horticulture in the present demography and called for the utilization of hydrophonic technology and vertical farming for enhancement of fresh horticultural produce for urban dwellers. Richard J. Stoner (Living Greens Farm Inc., Faribault, Minnesota, USA) delivered the keynote address on 'Economic incentives for vertical aeroponic farming'. He pointed out that an urban vertical aeroponic farm of 400 sq ft area has the distinct advantage of producing the same quantum of better-quality produce than a 1600 sq ft soil-based farm. He emphasized that with the right vertical aeroponic technology, good quality fresh food can be grown year round in a profitable manner. He stressed that the future of vertical aeroponic farming in India and worldwide depends on sound economics of scale that takes advantage of the latest technologies to deliver fresh produce and offers good profit margins for investment ventures. He discussed the quantum of water saving in vertical farming by quoting the example of a Dutch company 'PlantLab', which has

*A report on the International Conference on Vertical Farming, organized by the Vertical Farming Association (India), Mumbai; Association for Vertical Farming, Munich, Germany and the Society for Promotion of Horticulture, Bengaluru, under the aegis of ICAR, New Delhi. The conference was held at Hotel Taj West End, Bengaluru, on 2 and 3 November 2015.

developed a revolutionary high-tech growing concept for cultivation of plants in conditioned production units in the absence of sunlight. Besides saving 90% of the water used in normal horticulture, PlantLab has improved the photosynthetic efficiency to the tune of 15–18% as against 9% which is normally achieved under outdoor conditions. This has been made possible by the use of LED lighting of different spectra, thereby resulting in improved yields.

Mohan Bajikar (Vertical Farming Association (India), Mumbai) discussed the future potential of vertical farming in the Indian scenario.

Since vertical farming involves significant engineering know-how, including the design of structures and provision of adequate lighting within enclosed spaces, an exclusive session on technological developments and business case studies was organized, wherein speakers from various industries dwelt at length on the latest developments in the design of efficient structures and lighting systems for vertical farming and how they can be extrapolated in the Indian context. This was all the more relevant for India, since the country is blessed with varied agro-climatic zones, multitude of crops and dietary preferences. The choice of crops suited for vertical farming under Indian conditions was also debated. Leafy vegetables, especially the high-value ones like lettuce, celery, and cucurbits with export potential, tomato, capsicum, bottle brinjal, fruits like strawberry, and flowers like gerbera, carnation and anthurium were considered to be more relevant in the Indian context. This was followed by an exclusive session on prospects of vertical farming and its integration in urban architecture. During this session, speakers from across the globe shared their experiences with policies of urban planning and the need to integrate vertical farming into urban structures in a seamless manner. The energy involved in lighting vast expanses of growing surfaces was a matter of concern for the audience, which was well received. It unanimously decided that the lighting systems followed in the West may not be the best alternative for India. Therefore, we need to harness solar energy that is available in abundance to minimize the energy requirements of illuminating multi-storied growing structures. It was also decided to simultaneously harness the solar radiation in frugal vertical growing structures, which could be easily integrated into existing terraces and balconies. The fourth session was devoted to the vertical farming market in India, and the availability of essential infrastructure in the Indian market at present. The sessions were interspersed with panel discussions on the possible integration of vertical farming in India's agricultural mechanization process, opportunities/challenges of vertical farming in India, and the need for integration of vertical farming in urban planning and architecture. It was decided to develop a roadmap for three sustainable pilot vertical farm models for Indian conditions. In order to achieve this, it was decided to set up three working groups with representatives from academia, NGOs, local governments and the business sector. The conference ended on an optimistic note on the prospect of introducing vertical farming in India, in order to meet the nutritional needs of the ever-growing urban population. The limitations of vertical farming was also discussed by different speakers. Even though the technologies are available, they are restricted to the crop-growing conditions of the regions/countries where vertical farming has been implemented/practised in high-rise buildings and cannot be duplicated in other regions as a broad spectrum technology. Under such circumstances, the major limitations of vertical farming in inclined high-rise buildings are as follows:

1. Limited vegetable crops have been identified for the purpose. However, vegetable crops in vogue are being grown without any scientific validation.
2. No varieties/hybrids have been exclusively bred for the purpose of vertical farming. As a result, yield and quality of the produce cannot be guaranteed.
3. Production technologies and Good Agricultural Practices for these crops have not been standardized.
4. Presently, the high-rise inclined buildings are not built to suit vertical farming. There is a need to re-engineer the existing buildings by providing additional structures to suit the purpose.

The above limitations could be taken up as researchable issues. It is essential that all the high-rise buildings coming up in the smart cities/green cities and tier-two cities in the near future should be engineered in such a way that these buildings could be used for vertical farming.

The participants were divided into three groups and asked to formulate three projects of commercial importance. The group leaders presented the outline of the projects and were subsequently asked to submit detailed projects to the Vertical Farming Association (India), Mumbai.

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