



# Urban Rooftop Farming – Model for Sustainable Vegetable Production and Environmental Well-being

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## ABSTRACT

**Background:** Urban rooftop farming is a form of urban agriculture. Due to the scarcity of agricultural land in urban areas, rooftop farming is becoming popular in many countries. An experiment was conducted to grow herbs and vegetables in a small and sustainable urban rooftop farm in Nagpur City, India and the various ecological benefits of this form of urban agriculture were studied.

**Methods:** The experiment was conducted on a 230 sq ft rooftop area from July 2019 to March 2020. Environment friendly cultivation methods employed in the study include pest management by cultural means to produce pesticide-free vegetables, conversion of household green waste into compost for augmentation of soil nutrients and the use of harvested rain water and greywater for irrigation.

**Result:** The experiment resulted in the production of 61.7 kg of pesticide-free vegetables from an area of 230 sq ft using sustainable farming methods. Apart from this, the various ecological benefits obtained from the experiment point to the fact that sustainable urban rooftop farming can be an innovative means to promote urban agriculture without harming the environment.

**Key words:** Rooftop farming, Sustainable agriculture, Urban agriculture.

## INTRODUCTION

In an uncertain future of climate change and constrained resources, urban agriculture is widely viewed as a sustainable and scalable approach to improving food security (Pollard *et al.*, 2017). Urban rooftop farming is a form of urban agriculture. It is primarily concerned with the cultivation of plants on the rooftops of buildings in urban surroundings. Urban rooftop farming favours local food production (Sanyé-Mengual *et al.*, 2015a). It is a practice that is well-suited to enhancing food security in cities and reducing the environmental impact that results from long transportation distances that are common in conventional agriculture (Buehler and Junge, 2016).

The population of India is growing at a fast pace. This is a thing of great concern, as agricultural land resources are limited and conventional agricultural production can be increased only to a certain extent. Hence, there is a need for new and innovative strategies for increasing the production of food crops without any harmful effects on the environment. It could be a good option for local authorities to promote rooftop farming (Grard *et al.*, 2015). If urban rooftops are judiciously used for cultivating edible plants, several tonnes of produce could be harvested through rooftop farming in the cities. Urban and peri-urban agriculture could play an important role in safeguarding livelihoods and urban food security (Maconachie *et al.*, 2012).

Regarding the management of urban rooftop farms, crop planning may focus on selecting the vegetables with higher crop yield and establishing crop periods to produce year-round, while reducing the environmental impacts and economic costs of crops (Sanyé-Mengual *et al.*, 2015a). There are economic, social and environmental opportunities of local and efficient food production through innovative urban rooftop farming (Sanyé-Mengual *et al.*, 2015b).

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## MATERIALS AND METHODS

### Study area

Nagpur City (Coordinates: 21°9' N 79°5' E) is located in Maharashtra State in Central India. The rooftop farming experiment was carried out on the concrete rooftop of the author's house in Nagpur from July 2019 to March 2020 (Fig 1). Out of the total rooftop area of 900 sq ft available, approximately 230 sq ft area was used for cultivating edible plants.

### Materials used

Sixteen types of edible plants were cultivated as depicted in (Table 1). The plants were grown in clay pots and grow bags of suitable sizes depending on the type of plant. Common garden soil was used for cultivation. The soil depth was maintained at 8-25 inches depending on plant size. Pots/containers of diameters 9, 12 and 15 inches were used for cultivation and were filled with about 4.5 kg, 7 kg and 10 kg mixture of soil and compost, respectively.

### Cultivation method

Plants were cultivated directly from seeds except onion, garlic, lemongrass and mint. Plants of the same type were



**Fig 1:** A view of the urban rooftop farm where the study was conducted.

seeded at regular intervals to prolong the harvesting period and provide a continuous supply of produce.

### Composting

Household kitchen waste was converted into compost in a compost bin and applied to the soil for nutrient enrichment. No synthetic fertilizers or pesticides were applied during the course of the cultivation period.

### Water management

The plants were watered daily using a watering can. During the monsoon season, runoff from the rooftop was collected in a plastic barrel and was used for watering the plants on the days when rains did not occur. During the winter season, household greywater generated as a result of washing dishes and clothes was also used for watering the plants. No negative impact of greywater was observed on the growth of plants. Care was taken to ensure that greywater did not touch the edible parts of plants.

### Pest-monitoring and management

The plants were regularly monitored for the presence of pests. Whenever pests were observed, they were physically removed by hand and destroyed. Hence, only pest monitoring and cultural control methods were applied for managing pests.

### Harvesting

The produce was regularly harvested and weighed with a digital balance and a record was maintained.

## RESULTS AND DISCUSSION

A total of 61.7 kg of produce was harvested during the cultivation period beginning in July 2019 and ending in March 2020. As tomato plants were grown in approximately 40% of the containers, the tomato crop constitutes the largest portion of the total harvest. The harvest obtained from the different types of crops is depicted in (Table 1).

A total harvest of 61.7 kg of vegetables from a cultivated area of 230 sq ft means one kilogram of produce was

obtained per 3.65 sq ft of cultivated area. The total vegetable harvest would make approximately 20–25% of the annual vegetable consumption of a small family with three members. Since this harvest was obtained from only 25% of the available rooftop cultivated area, it shows that larger amounts of produce can be obtained by bringing a larger rooftop area under cultivation. This positive result again reinforces the importance of urban rooftops in increasing agricultural production. The following ecological benefits accrued as a result of following sustainable practices during the course of rooftop farming.

### Enrichment of soil with organic matter

Home composting (HC) has become an increasingly important consideration in the framework of sustainable municipal organic waste (MOW) management in developing countries (Loan *et al.*, 2019). The conversion of household kitchen waste into compost and its application for rooftop agriculture helped in enriching the soil with organic matter and micronutrients. This also reduced the amount of household waste entering the urban solid waste disposal facilities. Approximately 22 kg of kitchen waste was converted into compost and applied in equal amounts to the plants during flowering and fruiting periods.

### Conservation of water resources

Water is one of the major resources required for agriculture. During cultivation, the plants were directly watered by hand taking care that each plant received sufficient amount of water and that this water reached the soil around the plant and was not wasted by splashing on foliage. The use of stored rain water for irrigation helped in the conservation of water resources. Another method that was applied for

**Table 1:** Total quantity of agricultural produce harvested through urban rooftop farming.

Crop name	Harvested quantity	Number of containers used for cultivation
Amaranth	3.2 kg	3
Aubergine (Eggplant)	3.4 kg	3
Carrot	2.2 kg	4
Coriander	1.3 kg	4
Dolichos beans	1.5 kg	2
Fenugreek	1.5 kg	4
Garlic greens	1.7 kg	4
Green chillies	1.1 kg	3
Lady finger (Okra)	1.5 kg	5
Lemongrass	2.1 kg	1
Mint	1.1 kg	2
Mustard greens	1.2 kg	4
Onion greens	2.5 kg	4
Radish (including edible leaves)	3.5 kg	4
Spinach	6.7 kg	5
Tomato	27.2 kg	30
<b>Total quantity</b>	<b>61.7 kg</b>	<b>82</b>

watering plants was the use of greywater. Excluding human dejects, greywater comprises the outflow from washing machines, dishwashers and bathtubs. It is considered an effluent with a more economic treatment, because it contains less microbial pollution (Gorgich *et al.*, 2020). Greywater can be used for groundwater recharge, landscaping and plant growth (Al-Jayyousi, 2003). Reuse of greywater in rooftop agriculture not only helped in the conservation of water resources but also reduced the amount of household wastewater entering the sewage channel. Approximately 550 litres of freshwater was conserved during the cultivation period by the use of greywater for irrigation.

#### **Pest management by environment-friendly methods**

Cultural controls embody an array of potential pest-control tactics, ranging from initial cultivar selection to a sequence of agronomic practices starting before planting and ending after harvest (Summy and King, 1992). Cultural control methods were used for the management of pests in the rooftop farm. Different types of vegetable plants were placed together to make it difficult for pests to quickly spread to their preferred hosts. The plants were regularly monitored for the presence of pests. Two species of hemipteran pests were observed during the period of cultivation, namely, cotton aphid (*Aphis gossypii*) on dolichos beans and solenopsis mealybug (*Phenacoccus solenopsis*) on tomato. Individuals of both the pest species were removed by hand and destroyed before their populations could grow to a threshold level. No insecticides were used to control pests.

#### **Mitigation of the urban heat island effect**

Replacing vegetated surfaces with low albedo materials is one of the reasons for increasing temperatures in the urban environment and consequently also one of the key causes of the urban heat island effect (Razzaghmanesh *et al.*, 2016). Covering some part of the rooftop with green plants helped in reducing the amount of heat trapped by the building. This led to slightly lower ambient temperature in the part of the building directly under the rooftop farm.

#### **Reduction in greenhouse gas emissions**

The expansion of urban agriculture assists in reducing greenhouse gas (GHG) emissions not only by producing food but also by reducing the amount of food transported from farming areas and therefore reducing the food mileage (Lee *et al.*, 2015). As vegetables were cultivated and consumed at the same place, this eliminated the need for transporting them, which would have required the burning of fossil fuels. This way, urban rooftop agriculture helped in reducing the emission of greenhouse gases to some extent.

#### **Reduction in pollution**

Since plants naturally clean the air and sequester carbon, implementing green roofs on a wide scale provides opportunities to utilize these typically unused spaces to address these environmental issues (Rowe, 2018). In this context, the urban rooftop farm also doubled as a green

roof and helped in cleaning the polluted urban air. To some extent, cultivating plants on the rooftop also helped in replacing some amount of urban vegetation that was destroyed by the construction of the building.

#### **Increase in urban biodiversity**

Plant diversity and floral abundance in urban areas promote pollinating flower visitors (Hennig and Ghazoul, 2012). It was observed that the increase in green cover also resulted in a corresponding increase in animal diversity. Various insects such as honeybees, bumble bees, butterflies, moths and dipterans were frequently observed visiting flowers for foraging. Pollinators like honeybees and other types of wild bees were especially benefitted by the increase in vegetation. The presence of herbivores also attracted generalist predators like spiders and dragonflies as well as ladybird beetles that feed on aphids. This demonstrates that urban rooftop agriculture, in addition to providing food can also help in increasing urban biodiversity.

#### **CONCLUSION**

Based on the results of this study, it can be concluded that encouraging small-scale and sustainable urban rooftop agriculture in urban areas can not only constitute a new source of augmenting agricultural production, but it can also be environment-friendly and provide many ecological benefits to people and urban ecosystems.

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