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A case study of multilayer farming in Muradnagar Block of Ghaziabad: An approach for better yield and increased farm income

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Abstract

India has over 17% of world's population living on 2.4% the world's geographical area. In India, primarily farmers (about 85%) come under small and marginal farmers who practice contemporary agricultural methods with extensive use of fertilizers. The amount of arable land is lessening as a result of rapid population growth along with fast urbanization, land degradation due to soil erosion, and soil salinity. An innovative farming technique is the need of the hour not only to enhance crop productivity but also provide greater economic return per unit area. Multilayer farming is one such viable option to boost aggregate farm production and thus increase in farm income. Multilayer farming means growing and cultivating more than two crop at different heights on the same field at the same time. A study was undertaken in Ghaziabad district of Uttar Pradesh with the objective to demonstrate and create awareness among farming community about the benefits of multilayer farming and increase in farm profit. A pilot scale field experiment was conducted for consecutive two years in Ghaziabad district involving 8 farmers with one acre of land each growing various vegetable and fruit crops through multilayer farming technique. Various parameters like land equivalent ratio as an indicator of yield advantage of multi-crop farms over sole-crop farms, analysis of economics (benefit-cost ratio), impact of soil organic carbon and water on multilayer farming were investigated. The study effectively demonstrated effective utilization of vertical space and the participant farmers successfully cultivated three to four crops each season with LER value greater than unity. The study revealed increase in organic carbon percentage along with 30 percent less water consumption and benefit cost ratio of 2: 1 which was obtained on an average from one acre of land. Due to presence of more than two crops in the field helped farmers mitigate the risk of crop failure due to sudden change in weather conditions. Crops on bamboo structure had better quality produce which increased farm income. The paper highlights the benefits of cultivating multi-tier crop species for effective utilization of vertical space and different crop choices for higher monetary advantages.

Keywords: Multilayer farming, vegetable, food and nutritional security, crop diversity, intercropping, sustainable agriculture

Introduction

Global food production faces monumental challenges in today's context and will likely increase in the future if gaps are not addressed wisely. With future world population is projected to reach 9.8 billion in 2050, according to a United Nations report launched in 2017, coupled with rising urbanization, soil degradation, decreasing arable land, weather extremes due to climate change, disruptions in the food supply chain, and unpredictable shocks like global pandemic the need for resiliency in global food productions has become more pressing than ever (Gomiero, 2016; de Bruin *et al*., 2021; Savary *et al*. 2022) [9, 8, 26]. While over 50% of the world's population lives in cities today, by 2030, the number will rise to 70% (Eigenbrod & Gruda, 2014) [9].

Nutrition is one of the crucial elements for achieving the Sustainable Development Goals (SDGs), particularly SDG-2, "End hunger, achieve food security and improved nutrition and promote sustainable agriculture," and is also essential for the realization of other SDGs (Gyimah *et al*. 2023; Viana *et al*. 2022) [12, 29]. Marginal or smallholding farmers (with farmland spanning less than 2 hectares) are critical to eliminating hunger and malnutrition worldwide.

Macro and micronutrients are both essential for human growth and development. Fruits and vegetables are the major sources of micro-nutrients. It offers farmers a wide range of options for crop diversification and ample scope for sustaining several agro-industries, which generate substantial employment opportunities. Diversification of horticulture has emerged as the best option for addressing nutritional adequacy, enhancing employment opportunities, farm income, use of natural resources and emerging enterprises.

Decreased soil fertility and water availability, the need for yield expansion, and reducing negative environmental impact are still challenges in horticultural production. New cropping technologies have been established to address some of these issues (Kataki 2002; Orsini *et al*., 2013; Armanda *et al.* 2022) [14, 20, 3]. Despite the resource efficiency of indoor farming systems under controlled conditions, they are still costly and not farmer-friendly for small farm holders. Enhancing vegetable productivity by using new innovative methods and technologies is the best alternative to sustain the nutritional security of the growing population, and income security for small and marginal farmers is the need of the hour. An intercropping system can allow sustainability in agriculture by competent resource management, crop diversification and improving soil fertility (Maitra *et al*. 2021, Gou *et al.* 2022) [16, 11].

The multilayer farming (MLF) technique involving multispecies crop combinations is an innovative alternative agriculture practice for sustainable productivity that can provide greater economic return per unit area. This farming involves cultivating plants at different heights or growing two or more crops on the same piece of land, maximizing the farm land's utility. It includes the incorporation of fruits and vegetable crops in the same field. The key of the success of multi-store/multi-crop cropping system is the inclusion of crops with diverse features (growth habit, root depth and crop duration) in the same land area under cultivation. Growing more than one crop at a time in the same field helps to utilize natural resources like soil, water, sunlight, and nutrients competently. With the help of MLF, the farmer's income can be increased substantially per unit area as a mixture of different crop species has often been assimilated to a higher yield of the mixture when compared with monocultures. Water consumption, fertilizer and manures are saved, as the amount of water and fertilizer used in one crop is enough for 3 to 4 crops in MLF (Pramanik 2022) [24].

The MLF system is not a new technique of farming. Farm growers are practicing it for a long time as intercrop in their farm field. With the improvisation in this farming system made is the synergy of local knowledge of adopting appropriate crop (vegetable crops) combinations, its survivability in various environmental conditions and above all, the low risk of a complete crop failure, this farming technique is emerging as a promising and fitting strategy to boost income of small and marginal farmers. The benefits of MLF are highlighted in fig.1. The crop used in this farming system depends on the sequence of sowing methods, root zones, vegetative growth, and crop harvesting time. Sowing underground crops like Turmeric or Ginger utilizes the deep root zone. The short durational crops like green leafy vegetables (Coriander, Spinach, etc.) are sown as second layer on the surface of the soil. The tomato or green chilies/capsicum or creepers like cucumber on surface as third layer crop. Bitter gourd or bottle gourd or ridge gourd (climber/creeper plants) as fourth layer crop near bamboo pole's structure and fruiting takes place on the erected bamboo structure. Fruit plants (papaya and banana) plantation as the fifth crop at the periphery of the field as border crop. Pavilion/ platform on the top of the crop field is prepared with the help of bamboo, steel wires and grasses to cultivate creeper crops like bitter gourd or bottle gourd or ridge gourd as uppermost layer crop. It also protects the bottom layer of crops from sunlight, heavy rainfall and outbreaks of insects (Pramanik 2022) [24].

The present study aimed to demonstrate the Multilayer-Farming model among farmers of Muradnagar Block of Ghaziabad district in Uttar Pradesh (NCR region), India, to create awareness for new methods of crop cultivation. The study also focussed on the optimum utilization of the decreasing agricultural land due to rapid urbanization and increasing farmers' income (Fig. 2a-d).

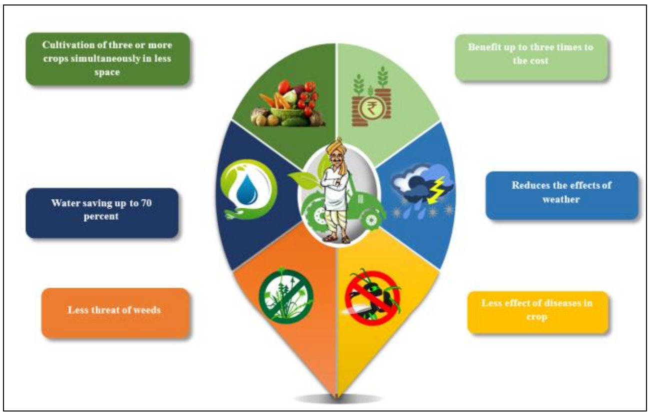


Fig 1: Major Benefits of Multilayer Farming system

Fig 2a: Multilayer farming in Ghaziabad District UP

Fig 2b: Inside view of Multilayer farming

Fig 2c: Top view of Multilayer farming with crops on bamboo structure

Fig 2d: Three different crops in one field at a time (Cucumber on ground, gourd family member on bamboo structure and papaya as border crop)

Materials and Methods

Location

The experiments were conducted with 10 acres of land in three nearby villages Rawli Kalan, Kunehda and Surana (Latitude: 28.8337895 and Longitude: 77.4415008) of Murad Nagar Block of District Ghaziabad, Uttar Pradesh, during kharif and rabi seasons for almost eleven months in a year) for two consecutive years in 2022 and 2023. Muradnagar Block of Ghaziabad District is close to Delhi NCR region. Farmers selected for this pilot project of were small farm holders and predominantly cultivated wheat and water-intensive sugarcane crop only. In this study data of only 8 farmers with unit plot size of one acre were considered. Data of remaining farmers of two acres were omitted as farmers failed to carry out the experiments as per the plan and farm unit size was less than one acre. The project timelines are represented as flow chart in Fig. 3**.**

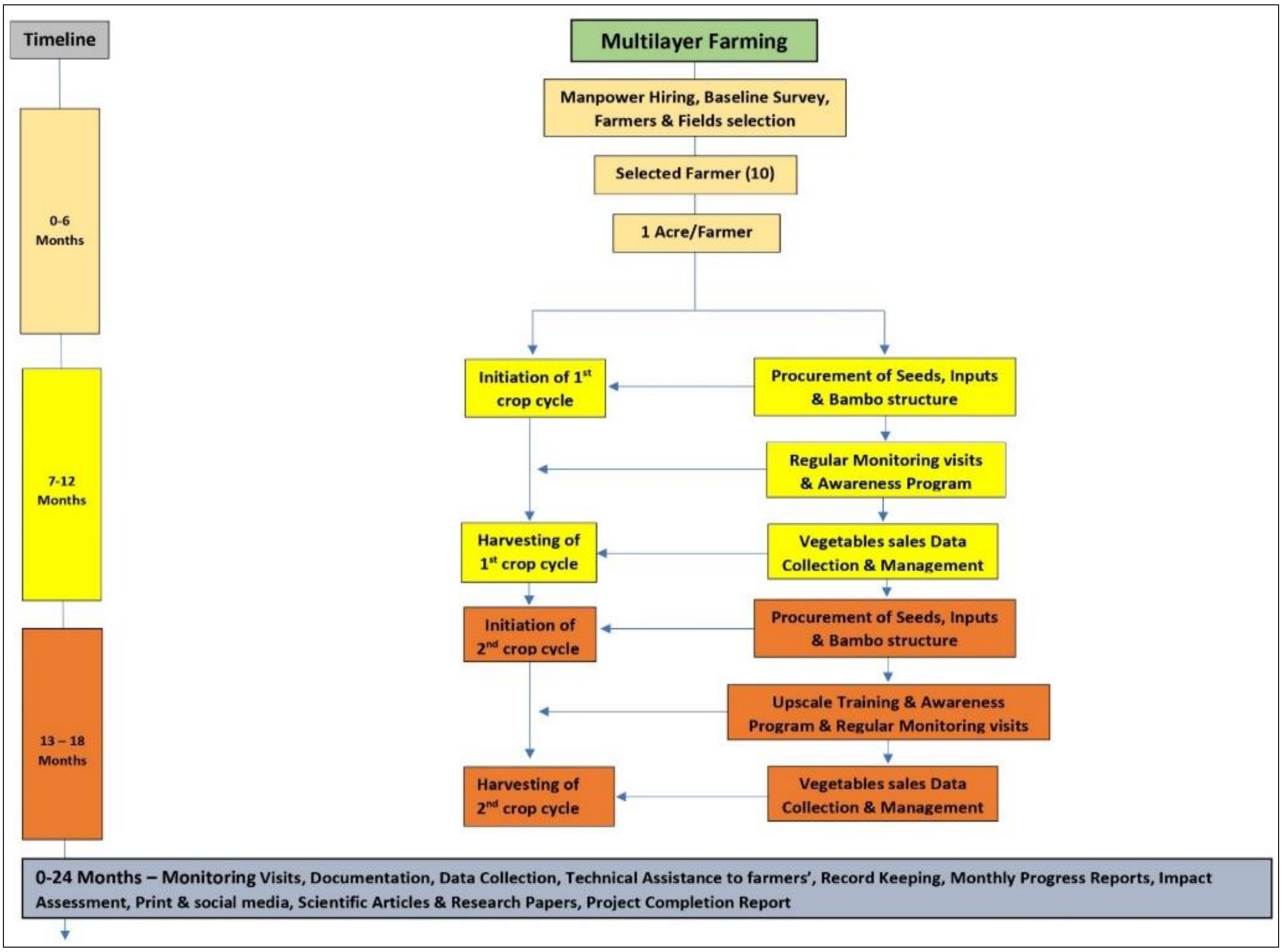


Fig 3: Schematic representation of the experimentation and timelines

Soil

The experiments were established in sandy loam soil with an average pH range 8.4-8.5, NPK was in the range of 90-150, 23-31 105-263 respectively available kg/hectare and a percentage organic carbon was 0.24-0.31.

Irrigation

Irrigation of vegetable crops was done through channels and 45±2 hours of water consumption (8,10,000 liters) per year of irrigation was required during the total crop duration. Irrigation was done through 7.5 hp where the average discharge of 5-liter sec^{-1} was recorded.

Vegetable

The selection of vegetable crop species and varieties was according to the local soil profile and ecological zone. The farmers were allowed to select 3-4 crops of their choice in both the crop cycle season. The variety, crop duration, crop spacing for selected vegetable crops in the multilayer field by eight farmers for both years are represented in Table 1**.**

Thirty days old seedlings of onion, selected vegetables of the Cucurbitaceae family (bitter gourd, bottle gourd ridge gourd, cucumber), tomato, capsicum, papaya and chili of vigorous, healthy and uniform growth were selected and transplanted to the farm field. The farmers practiced protective farming techniques like low polytunnel to sow seeds in harsh winter conditions.

Crop Combination for MLF adopted by Muradnagar block farmers under the project

1. **First crop:** Turmeric/Onion as underground crops
2. **Second crop:** Green leafy vegetables (Coriander, Spinach, Fenugreek and green vegetables etc.) as short-duration crops (Seasonal)
3. **Third Crop:** Cucumber or Pointed gourd etc. (creepers) as surface crops
4. **Fourth Crop:** Ridge Gourd, Bitter Gourd, Bottle Gourd etc. for utilizing the vertical space (trailed with the help of a framed structure made of bamboo, steel wires and sutli/thread)
5. **Fifth Crop:** Papaya/Banana (any fruit crop planted at the edges of the field)

Table 1: Selected vegetable crops by 8 farmers in the multilayer field in Ghaziabad district for two years. Each farmer cultivated 3-4 crops from the list tabulated below

Sr. No.	Name of crop (scientific name)	Variety of crop	Crop duration (sowing to harvest)	Layer wrt MLF	Crop Spacing
1	Onion (*Allium cepa*)	N-53	June to November	Underground	20 cm x 15 cm
2	Turmeric (*Curcuma longa*)	Swarna	May to March	Underground	20 cm x 15 cm
3	Coriander (*Coriandrum sativum*)	Mehak	September to October	Surface	5 cm x 5 cm
4	Spinach (*Spinacia oleracea*)	Green Wonder	September to October	Surface	5 cm x 5 cm
5	Papaya (*Carica papaya*)	Red lady 786	June (24 Months Crop)	Periphery/ Border (above the bamboo structure)	1.8 m X1.8 m
7	Cucumber (*Cucumus sativus*)	Encounter	June to September	Surface	20 cm x 150 cm
8	Ridge Gourd (*Luffa acutangular*)	Satya	June to October	On the bamboo structure	2.5 m x 2 m
9	Bottle Gourd (*Lagenaria siceraria*)	Alok	June to October	On the bamboo structure	2.5 m x 2 m
10	Bitter Gourd (*Momordica charantia*)	Pragati	June to October	On the bamboo structure	2.5 m x 2 m
11	Tomato (*Solanum lycopersicum*)	M-Sona	Feb to June	Surface	60 cm x 90 cm
12	Capsicum (*Capsicum annuum*)	RHS Chand F1	March to June	Surface	60 cm x 90 cm
13	Chilli (*Capsicum frutescens*)	Soldier	March to June	Surface	60 cm x 90 cm
14	Okra (*Abelmoschus esculentus*)	Padmini	June to August	Surface	45 cm X 30 cm
15	Radish (*Raphanus sativus*)	Punjab choice	October to November	Surface	15 cm x 10 cm
16	Mustard (*Brassica nigra*)	Pioneer 45S46	September to November	Surface	45 cm X 15 cm
17	Cauliflower (*Brassica oleracea* var. *botrytis*)	White Pistol	September to November	Surface	45 cm X 15 cm

Weedicide and Fertilizer

Weeds were controlled manually with a hoe as per the need. The farmers used native hoe for weedicide. Diammonium Phosphate (DAP) fertilizer was applied at a dose of 50 Kg/acre at the time of sowing, 50 Kg/acre of NPK and potash each at the time of the vegetative stage of the majority of crops and 25 Kg/acre of calcium nitrate at pre-flowering to the fruiting stage. Additionally, 1.5 tons of farmyard manure per acre was applied.

Benefit-cost ratio

Crops were harvested at maturity and yield data were collected for the first year and second year. Harvested crops were sold in the local market and income from vegetable produce was recorded by each farm. A survey was conducted in three villages concerning water consumption in multilayer vegetable farming and the cultivation of sugarcane and wheat crops. The input cost used for calculating the benefit-cost ratio involved the cost of hiring labor, fertilizers, vertical bamboo structure for MLF, investment in land preparation, seeds, seed sowing, weeding, harvesting, returns in terms of crop yield and household income. A specially designed questionnaire was used for data collection.

Data analysis

Data was collected from 8 farmers practicing multilayer vegetable farming from land preparation until harvesting through personal interviews and on-farm observations for the first and second crop seasons. The predominantly quantitative data was analyzed using tabular analysis and visualized in histograms and pie charts. The results were interpreted by adopting the analytic generalization method. Analytic generalization occurs most keenly at the point of analysis and interpretation. Through rigorous inductive analysis and confirmatory strategies, researchers would arrive at insightful, inductive generalizations regarding the phenomenon under study (Polit and Beck, 2010) [23]. Analytic generalization is suitable for the case study research method. If a case or more cases validate the same theory, replication can be claimed and researchers are concerned with replication logic and theory rather than the sampling logic (Yin, 2009) [32]. The present study adopted the Land Equivalent Ratio (LER) and Benefit-cost ratio for interpretation and analytic generalization of results.

Land equivalent ratio (LER) and Benefit-cost ratio (B: C ratio) were calculated by the following formula:

Land equivalent ratio (LER)

When two or more crops are cultivated together in the same area, yield advantages happen because of variances in their use of available resources. The land equivalent ratio (LER) is the most commonly accepted index in intercropping/ multi-cropping systems to evaluate the land productivity and efficacy of intercropping (Brintha and Seran, 2009) [6].

It is formulated as follows

LER=∑(Ypi/Ymi) where Yp is the yield of each crop or

variety in the intercrop or polyculture, and Ym is the yield of each crop or variety in the sole crop or monoculture.
For each crop (i) a ratio is calculated to determine the partial LER for that crop; the partial LERs are summed to give the total LER for the intercrop (Dariush *et al*., 2006) [7]. A LER value of 1.0, indicates no difference in yield between the intercrop and the collection of monocultures (Mazaheri and Oveysi, 2004) [17]. Any value greater than 1.0 indicates a yield advantage for intercrop.

Benefit-cost ratio (Net return/cost of cultivation)

The net return and benefit-cost ratio (BCR) were derived based on the prevailing market price of inputs and outputs cost on acre basis. The net profit was calculated by subtracting total cost of cultivation from the total returns obtained from sale of crop yield on the existing price in rupees. The data for the selling price of cultivated vegetables of MLF project was collected through questionnaires from participant farmers (Rymbai *et al*., 2012) [26].

Results and Discussion

All eight farmers who participated in the demonstration study were small farm holders. Each participant farmer of the study could successfully cultivate at least three crops (second, third and fourth crop level) per crop cycle (Table.2). While comparing the different intercrop combinations of each farm, it is interesting to note from Table 2 that for all the farms for both years of study, aggregate production of multiple crops per unit land area was boosted with the selection of these vegetables. It was observed that for all farms, the LER was greater than unity (1.0) for both seasons, indicating the intercropping system's advantages (Maitra *et al*., 2021) [16]. LER values larger than 1 indicate a yield benefit for an intercrop over a mono-crop, possibly due to positive interference among the components of multi-crop varieties (Morales-Rosales and Franco-Mora, 2009) [19]. The yield per acre per vegetable (monocrop data) was considered from ICAR website (https://agritech.tnau.ac.in/horticulture/horti_vegetables.html dated 4th January, 2024). LER-based studies have demonstrated that increasing species richness in multiple crops has measurable yield, biomass and weed suppression benefits. This study is in agreement with related studies mentioned by Yu *et al*., 2015 [33] and Mohammed 2012 [18].

Table 2: Crops cultivated, LER and benefit-cost (B:C) ratio in one acre (8 farms) of land for crop cycle of the first year and second year

Farm no.	Crop Cycle	Crops cultivated	LER	B: C ratio
1	First year	Cucumber, Ridge gourd, Coriander	4.12	1.17
	Second Year	Cucumber, Ridge Gourd, Bitter Gourd, Capsicum	2.6	1.17
2	First Year	Cucumber, Bottle Gourd, Bitter Gourd, Coriander	3.15	2.63
	Second Year	Cucumber, Bottle Gourd, Bitter Gourd, Coriander	3.97	2.5
3	First Year	Cucumber, Tomato, Bitter Gourd, Coriander	4.82	0.88
	Second Year	Cucumber, Bottle Gourd, Bitter Gourd, Capsicum	1.06	2.28
4	First Year	Cucumber, Bottle Gourd, Bitter Gourd, Coriander	2.89	1.39
	Second Year	Cucumber, Bitter Gourd, Bottle Gourd	2.82	1.10
5	First Year	Cucumber, Bottle Gourd, Bitter Gourd, Coriander	1.14	0.40
	Second Year	Cucumber, Bitter Gourd, Tomato, Cauliflower, Coriander	3.18	1.48
6	First Year	Cucumber, Bottle Gourd, Bitter Gourd, Coriander, Spinach	0.80	0.44
	Second Year	Cucumber, Bitter Gourd, Tomato, Chili, Capsicum Ridge Gourd	4.25	2.07
7	First Year	Bitter Gourd, Marigold, Coriander	1.13	1.94
	Second Year	Cucumber, Bitter Gourd, Coriander, Spinach, Radish, Mustard	2.44	2.37
8	First Year	Cucumber, Bitter Gourd, Coriander	4.87	0.86
	Second Year	Radish, Spinach, Ridge Gourd, Bottle Gourd, Bitter Gourd	1.22	1.24

It is noted from Fig. 4 a-h, that farmers spent the maximum in labor charges (29-37%) followed by cost of seeds, pesticides and weedicides. Interestingly, in each farm, the cost of fertilizers and land preparation was the lowest among all the input costs for cultivating one acre of multilayer vegetable farming for two cropping seasons. Various studies have concluded that in vegetable cultivation, which is labor-intensive farming, a significant proportion of capital (input cost) is used on human labor (Sidhu *et al*., 2009, Tiwari and Tiwari 2018) [28, 29]. The average benefit-cost ratio for all eight farms of one acre for two years of study was 1.9, meaning when a farmer invested Re. 1, the benefit of Rs. 1.9 was received after selling the farm produce. The variation in benefit-cost ratio is due to the variation in input cost like labor charges, increase in the selling price of the crop sold during offseason and non-performance of first- and fifth-layer crops (Fig. 4, Table 2 and 3). Cases involving first (underground crops) and fifth levels (border crops) did not perform as planned. This needs further investigation (Table 2 and 3). It is well-known fact that the cultivation of more than one crop as intercrop yields multiple produce leading to better income (Patil *et al*., 2019; Parte *et al*., 2020) [22, 21].

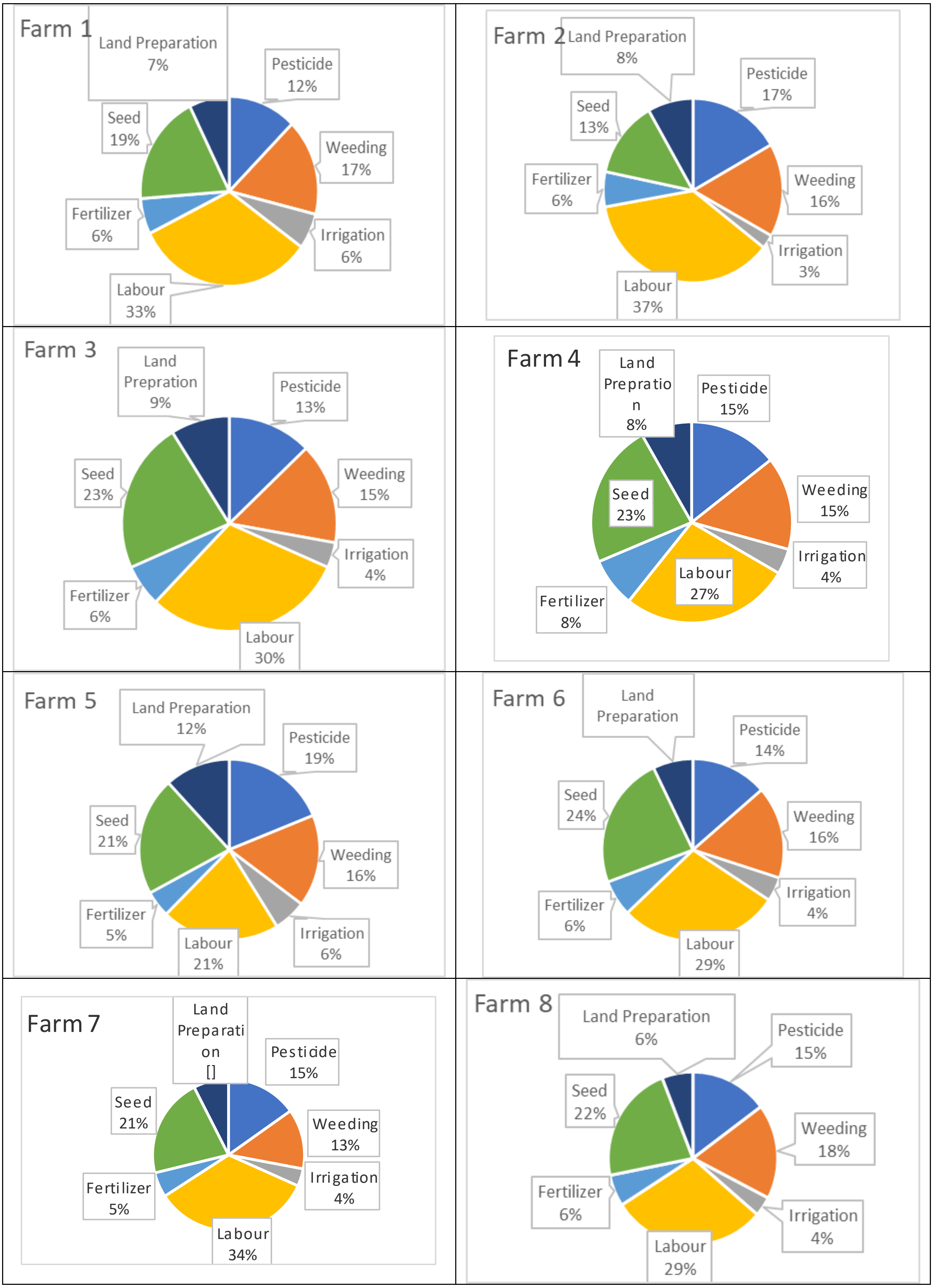
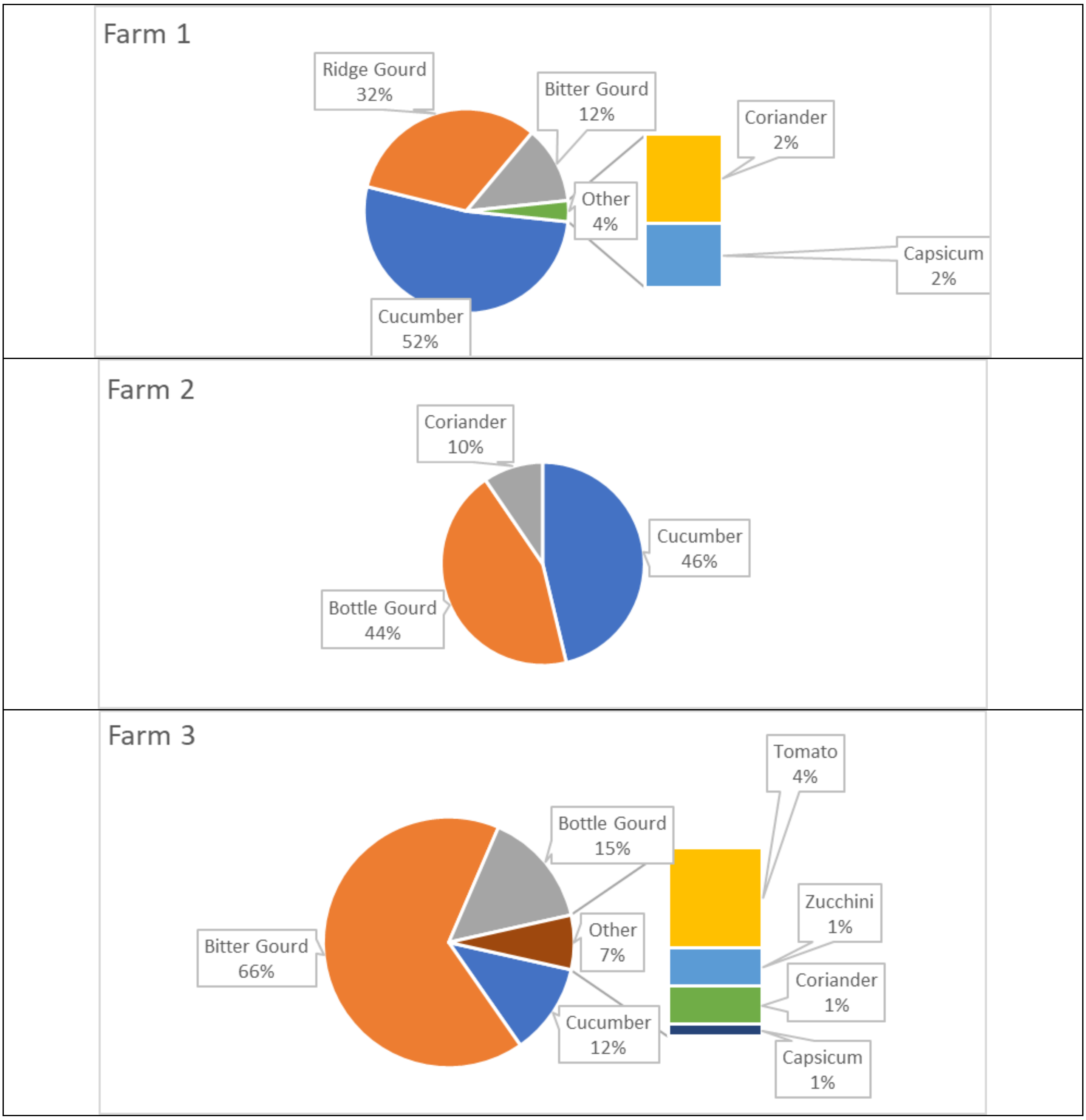
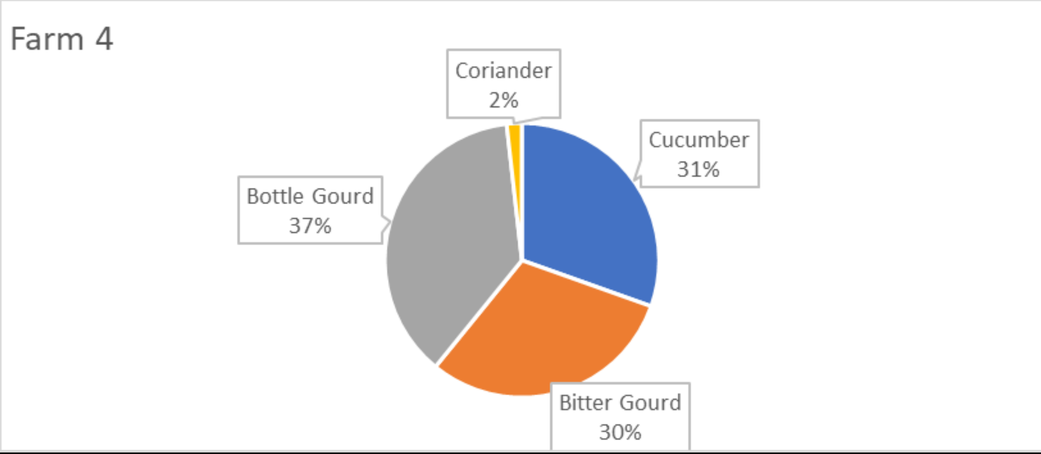


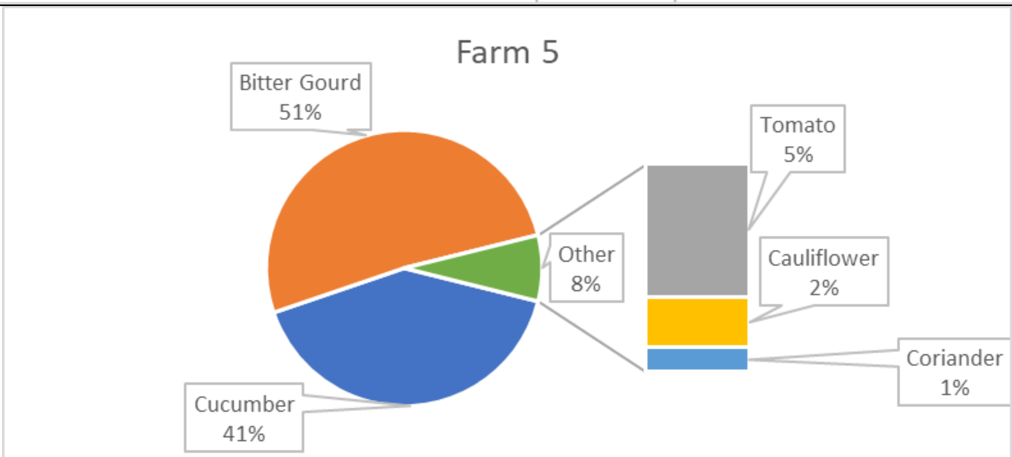
Fig 4 a-h: Percentage input cost in each farm/acre

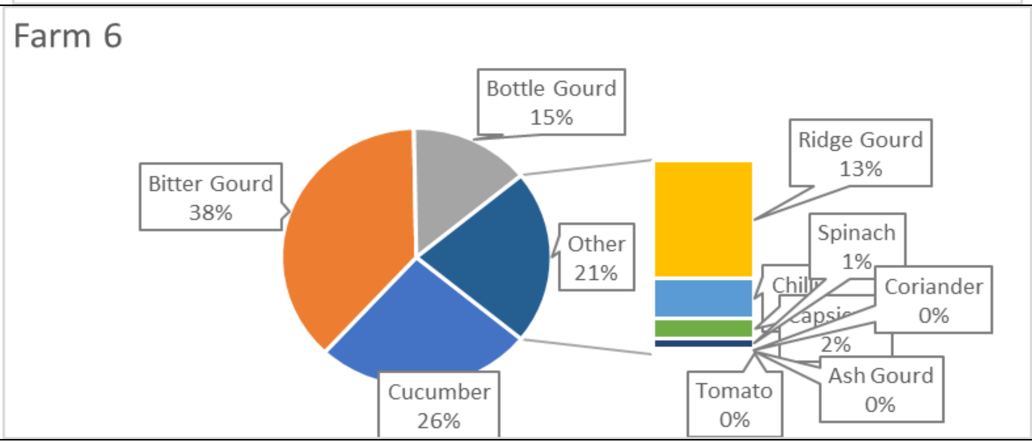
Table 3: Total production (Kg/ 8 acres) of individual crops and its income in Rupees from eight farms of one acre each under the study. Numbers of farmers preferred cultivation of the particular crop is represented brackets.

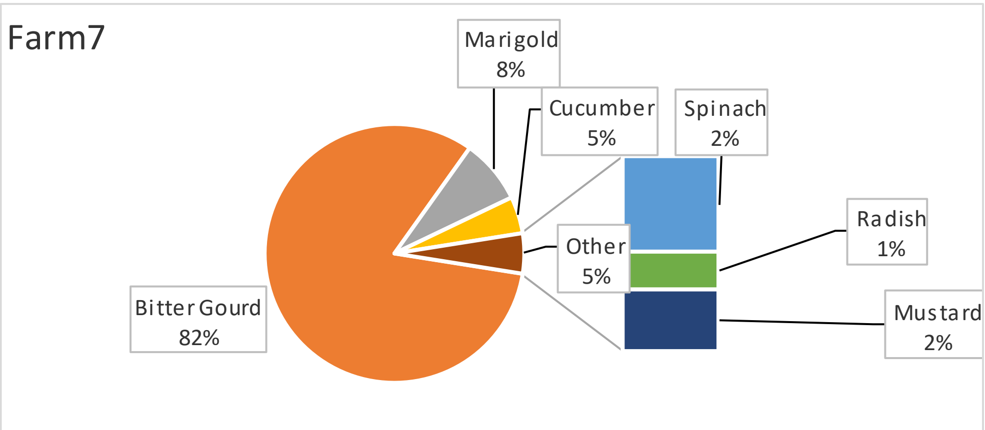
Crop cultivated	Production (# farmers cultivated) Kg/acre			Income (Rs.)		
	1st year	2nd year	Total	1st year	2nd year	Total
Cucumber	99967 (7)	44939(7)	144906	353929	437905	791834
Ridge gourd	3396 (1)	7864 (3)	11260	61193	306508	367701
Bottle gourd	13895 (4)	14817 (4)	28712	180805	198756	379561
Bitter Gourd	38528 (7)	45458 (8)	83986	911302	901373	1812675
Coriander	12683 (8)	1682 (3)	14365	52565	14790	67355
Capsicum	nil	503 (3)	503	nil	16708	16708
Tomato	960 (1)	1699 (2)	2659	16570	12880	29450
Chili	430 (1)	406 (1)	836	21320	18935	40255
Spinach	200 (1)	823 (2)	1347	4830	17380	27925
Marigold	766 (1)	nil	766	46545	nil	46545
Zucchini	nil	258 (1)	258	nil	6960	6960
Okra	nil	634 (1)	634	nil	14334	14434
Radish	Nil	2331(2)	2331	Nil	20718	20718
Mustard	Nil	970 (2)	970	Nil	11992	11992
cauliflower	nil	190 (1)	190	Nil	4270	4270




Farm 4
Coriander 2%
Cucumber 31%
Bottle Gourd 37%
Bitter Gourd 30%


Farm 5
Bitter Gourd 51%
Tomato 5%
Other 8%
Cauliflower 2%
Coriander 1%
Cucumber 41%


Farm 6
Bottle Gourd 15%
Ridge Gourd 13%
Bitter Gourd 38%
Spinach 1%
Other 21%
Coriander 0%
2%
Ash Gourd 0%
Tomato 0%
Cucumber 26%


Farm7
Marigold 8%
Cucumber 5%
Spinach 2%
Radish 1%
Other 5%
Bitter Gourd 82%
Mustard 2%

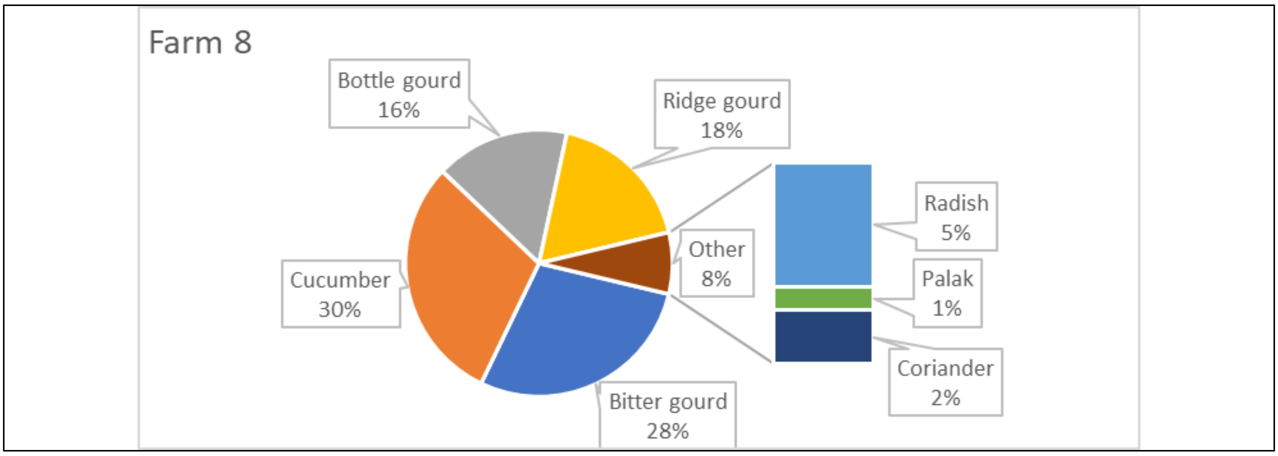


Fig 5 a-h: Percentage contribution of total income type according to vegetable grown per farm (one acre each)

Yield performance and income data per farm for all the cultivated crops for both the years of study were examined to assess the performance of the MLF system (Table 3 and Fig. 5a-h). Farmers majorly preferred the cultivation of cucumber as a trailing crop on ground, Cucurbitaceae family member (bitter, bottle and ridge gourd) on bamboo structure, coriander as well as spinach as surface crop and Solanaceae family member (tomato, capsicum, chili) in both the cropping seasons. This is very evident from Table 3 as yield and income were better with choices of these vegetable crops throughout the year. Interestingly, the percentage production of gourd (bitter/bottle/ridge) family members was highest in each farm of one acre (Fig.5a-h) for two years of study. Crop choice is an important consideration concerning the growing situation, crop environment of a locality, suitability of the crop, and demand and availability of a particular variety (Maitra *et al*., 2021) [16]. The species and variety of vegetable plants should be carefully considered taking account of the local environmental conditions including soil profile. The selected crops under the study showed optimum growth which was supported by local ecological conditions as mentioned in Maitra *et al*., 2021 [16].

The income from the bitter gourd was the highest, followed by cucumber and bottle gourd (Table 3). These crops' production was observed to be higher and also fetched better prices. In general, climber vegetables of the Cucurbitaceae family prefer proper support for their growth and development. Hence under the study, special bamboo structures were erected twining vegetables (Bitter/bottle/ridge gourds) that protected the produce from soiling and increased exposure to sunlight and aeration, thereby increasing the number of flower buds, ultimately resulting in more fruit of superior size and quality. Due to the bamboo structure, farmers could take more than two crops per season simultaneously, one being on the surface and the other on the bamboo structure. Moreover, the quality of the produce of the climber crops grown with the help of bamboo structure was comparatively better in shape and size, hence fetched better prices in the market for the harvested produce. This is in agreement with the studies by several scientists (https://eng.kisanofindia.com/latest-news/bitter-gourd-farming-by-pandal-technique/dated 6.2.24) It was noted that there was a demand for gourd family members in the local market and the average range of selling price of gourd was Rs. 5-45. The high range gap was due to off-season and seasonal selling prices of gourd family members i.e., selling price of the gourd in season was Rs. 5 and off-season selling price was Rs. 45/-). In the second year of crop cycle, the farmers preferred cultivation of capsicum, chili and tomato as surface crops. These crops fetched better price and the average range of selling price of these crops were Rs. 20-40, Rs. 49-65 and Rs. 15-33, respectively. Only few farmers preferred the cultivation of nutritious leafy vegetable spinach and although its production was less (Table 3) but it could fetch a good amount in the local market. The production of spinach and capsicum was less than the average standard yield as these crops were damaged due to unexpected rainfall in July-August 2023 in the Ghaziabad district. Due to unexpected changes in weather conditions cucumber crops were also damaged; hence, average production was less than expected (Table 3). In spite of weather challenges of unforeseen weather conditions, the farmer's income was not drastically affected due to the presence of other crops in the field. Intercropping of more than two crops is one of the most promising cultivation practice systems for smallholder farmers due to the shortage of land, and the practice safeguards the evading of risks associated with complete crop failure (Hong *et al*., 2020; Yang *et al*., 2021; Rongpharpi *et al*., 2022) [13, 32, 25]. From a nutritional point of view, gourd vegetables are pretty valuable as they contain significant minerals and nutrients (Azid and Ishak 2018; Agata and Beata 2020; Ahmad *et al*., 2022) [5, 1, 2]. Gourds have a high moisture content and contain many dietary fibers. Bitter gourd has a higher nutritional profile than other cucurbitaceous vegetables. The immature fruit is an excellent dietary source of ascorbic acid, beta-carotene, folic acid, vitamin A, calcium, phosphorus, and iron (Arun *et al*., 2021) [4].

Multilayer cropping is an attractive and simple practice that improves crop yield by increasing the total aggregate productivity of crop per unit area per unit of time (Table 3). Higher production and number of vegetables grown in multilayer farms resulted in increased spread of harvest time and longer spread for market income. It is motivating to note that vegetable farming through channel irrigation led to about 30% less water consumption than sugarcane farming, which is the main crop of cultivation in the region under study. The water consumption during the total crop production in a year for sugarcane farming was 65±2 hours (1170000 liters) whereas multilayer layer vegetable farming consumed 45±2 hours of water (8,10,000 liters) per year. Irrigation was done through 7.5 hp where the average discharge of 5-liter sec^{-1} was recorded (Fig.6 and Table 4). This is in agreement with the fact that intercropping can increase the water use efficiency of crops (Wen *et al*., 2020) [31]. Additionally, soil moisture holding capacity also improved owing to the natural build-up of shade due to the growth of climber crops on the bamboo structure. With the inclusion of diversity in multilayered farming, the quality and nutrition content in the soil improved wrt nitrogen, phosphorus and organic carbon content and pH level. The improved soil parameters include the average pH range which was 7.9-8.2, NPK was in the range of 135-290, 28-73, 61-140, respectively available kg/hectare and a percentage organic carbon was 0.40 -0.66. The possible reasons for the improvement in soil quality parameters are the preference of usage of farm yard manure, consumption of relatively less chemicals during land preparation and the addition of crop residue in the soil after harvesting of the crops. It is presumed that due to richness in biodiversity because of the cultivation of diverse crop species also leads in increase in counts of beneficial microbes in nutrient management (Lange *et al*., 2015) [15].

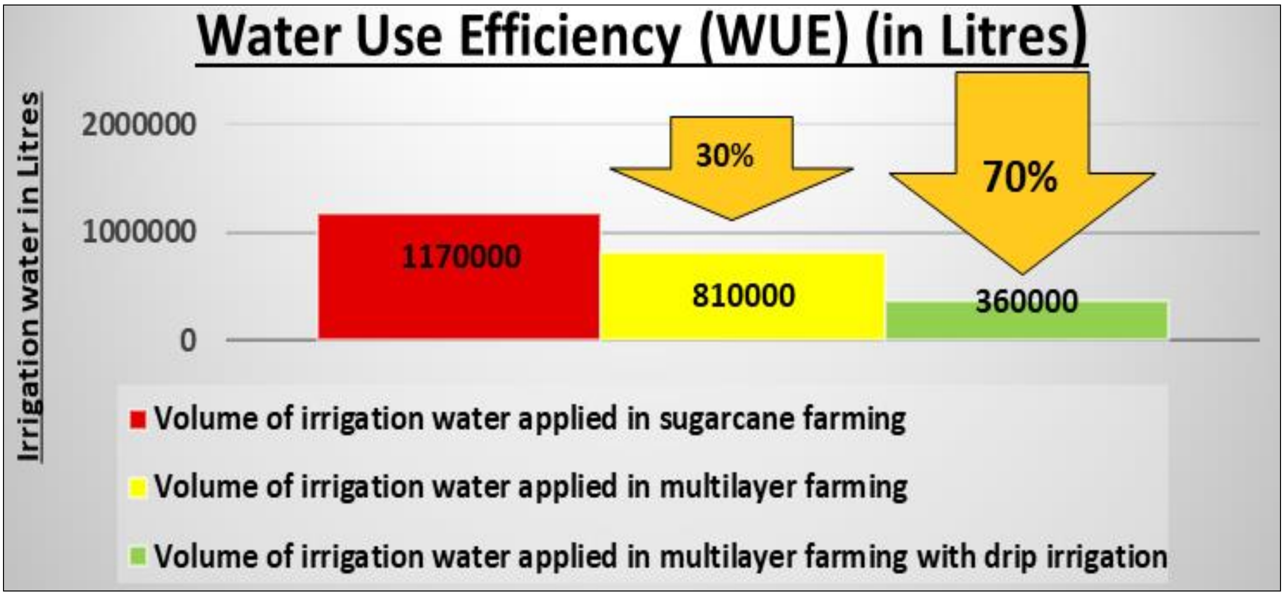


Fig 6: Water use efficiency in litres for sugarcane and MLF in area under study

The Baseline study was carried out through questionnaire in area under study for cost economics of sugarcane, wheat and MLF of vegetable produce. The survey revealed that in Muradnagar block, Ghaziabad district is majorly a sugarcane belt where the farmers mostly cultivated sugarcane and wheat prior to the adoption of MLF methods. The comparative cost economics of sugarcane and wheat are tabulated in Table 4. It was interesting to note in the study that per acre net returns from the composite yield of different horticultural crops of MLF is relatively higher than the net returns of mono-cropping of the preferred selected crops in the study area (Table 4). More over vegetable produce and its sale in local markets allowed farmers to gain monetary benefits all-round the year compared to sale from sugarcane or wheat production through MSP which is the guaranteed amount paid to farmers when the government buys their produce. Hence, it was presumed that farmers with small-size landholdings can reap the advantage from the composite yield of different crops (vegetables and fruits) cultivated under such a multilayer cropping system.

Table 4: Comparison between conventional farming of wheat and sugarcane together and MLF in Muradnagar block in Ghaziabad District for one year per acre

Sl. No.	Particulars	Traditional/Conventional Farming (Pre-Project)	MLF (Post Project)
1.	No. of Crops	2 (sugarcane and wheat)	3 or more crops
2.	Engagement of land (in months)	16	12
3.	Yield/acre (kgs)	41,800	19,200
4.	Input cost (Rs.)	89,650	1,02,625
5.	Farm income (Rs.)	1,70,250	3,02,796
6.	Profit earned (Rs.)	80,600	2,00,171
7.	Benefit-cost Ratio	Around 0.90:1	2:1
8.	Irrigation water consumption (in hours); Discharge of water at the rate of 5 litres/sec was recorded at a tubewell having power 7.5 hp motor	Sugarcane is a water-intensive crop Requires 65 hours of irrigation water (1170000 liters)	Consumes 30% less water in comparison to sugarcane Requires 45 hours of irrigation water (810000 liters)

Conclusions

The MLF model is quite effective and appropriate for small and marginal farmers with limited farm mechanization and ample scope for marketing vegetables or processing surplus vegetable produce. This farming method upsurges the net sown area, lessens the input cost and significantly enriches the fertility of the soil. Year-round production of vegetables fetches good returns from the sale of vegetables as Muradnagar block is in NCR region. Intercropping and multilayer cropping should be promoted as it involves diverse multispecies and has comparatively low input which can be agricultural strategy for food and environmental security. In this case study, the farming model was started with 12 participating farmers of villages Rawli Kalan, Kunehda and Surana in block Muradnagar of Ghaziabad district with four to five vegetable combinations for two cropping seasons (data of eight farmers were taken under consideration in this study). In two years, MLF technique was adopted and has scaled up many fold households in Muradnagar block. More than 100 farmers from these three villages adopted MLF technique in the year FY 23-24. The farmers used innovative technologies like low tunnel protective farming for off-season crops in their second cycle crop season to extend their profit and minimize losses incurred due to sudden change in local weather conditions like rainfall. Taking into consideration of input and profit analysis in this study, it is advisable to cultivate gourd family crops (Bitter/ridge/bottle gourd) on bamboo structure coupled with a surface crop like spinach, mint, coriander etc as the combination of these crops gave better monetary gain. Farmers in this area under study can be additionally encouraged to grow exotic high-value vegetables like zucchini, capsicum, and kale as these crops fetched higher prices provided, they have better accessibility to market facilities. It was noted that hired labour cost was responsible for the major input cost of vegetable farming in the study, hence if farmers can reduce the input cost of hired labour by family labours or pooling labour resources through formation of Farmers Producer Organisation (FPO) for horticulture crops, then the profit margin will be better. Farmers should be made aware of the marketing trends and skills along with of the importance of diversification for optimum utilization of family labour or pooling of labour resources which otherwise remains underutilized sometimes. The youth should be motivated to enhance their skills and practise vegetable farming using modern technologies as vegetables and fruits are increasingly recognized as important sources of food and nutrition security.

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