**Green leafy vegetable (GLV) production in open field and hydroponic units –Comparison of its economics and potential externalities**

**Abstract**

 GLVs are perceived to be health promoters, with its rich nutrient, fibers and freshness for consumers while for producers it's a quick cash crop with least investment when grown in open field. Of late, it is grown in controlled environment in hydroponic set up even in India. Both these production systems differ in terms of investment, costing and income on producer side and consumer group and pricing on the market side. To enable comparison, coriander, palak and fenugreek crops were selected, while over 15-20 un-identical crops were produced in both systems. 36 farmers producing GLVs in open and 18 producers of hydroponic system provided the required data and information. The analysis revealed that though costs were the lowest (less than 1/3rd) and fixed cost was negligible in open field conditions, income was thrice higher in hydroponic system which attracted substantial fixed cost investment of Rs. 45-50 lakhs/acre. The latter exhibited a higher land use efficiency because of vertical farming as well as use of technical inputs of precision farming. In addition, while open field GLV growers face price volatility, the hydroponic units with exclusive marketing arrangement sell at assured prices. While consumer groups differ for the two due to price reasons, traditional consumers believe open field grown GLVs are safer as they are unaware of use of substantial chemical inputs even for such short duration crops both as nutrient and crop protection. Insecticides, fungicides and pre-emergent weedicides used in open field conditions could carry chemical residues with potential health risks. In relation, hydroponic GLV production uses chemical nutrients, while bio-based nutrient use is also picking up. Prima facie, the hydroponic GLVs seem relatively safer than open field counterpart, while empirical evidence is awaited.

**Introduction**

Green leafy vegetables being plenty in nutrients and fibres are essential for a healthy diet. They account for over 15 per cent of the daily vegetable intake in Karnataka households. For producers, it’s a quick cash crop with short crop cycle, about a month from sowing to harvest. Its production is more predominant among peri-urban areas (eg., Pune, Mumbai, Delhi, Bangalore, Mysore, Hubli etc) catering to the needs of immediate neighbourhood towns/cities, while in some pockets GLVs are produced for fairly distant markets (Belgaum to Mumbai, Kolar to Chennai etc) also. Farmers traditionally produce it in open conditions both as a pure crop as well as an intercrop amidst some fruit crops. Such a practice is more common among resource poor farmers. Of late, its production in hydroponic setup is being undertaken by relatively richer and educated farmers. Such producers use resources intensively, making best of the outcome. Investment being substantial, returns are also expected to be proportionate.

The past studies pertaining to economics of GLV production mostly study cost and returns of its production under either of the two systems separately and hence a comparison of relative profitability in a given area and time duration is mostly lacking. Such a comparison shall throw light on relative profitability of the two systems, while in addition assessing the investment requirements of the two. Farmers willing to adopt the modern technology will get an approximate investment requirement. This paper is an attempt to fill this gap.

**Alternative production systems for GLVs**

The GLV production supports multitude farmer categories *viz.*, open growers (small holders), perennial orchard holders and capital intensive farmers etc. Being a short duration crop, they can be grown as intercrop or as mixed crop with some of the fruit crops like mango and watermelon or even in roof gardening. The first two scenario/systems are analyzed in this paper. Each of the production system could differ in terms of cost & return structure, clientele, price and marketing channel pursued. Since economic comparison is pursued, crops grown commonly in both systems *viz.,* Palak, Fenugreek and Coriander were considered. These three GLVs are predominately consumed in India, further being commonly grown under both open and hydroponic systems.

The advent of technology in vegetable (short duration) farming under controlled atmosphere was inevitable for temperate countries where climatic conditions were not suitable for farming especially during winter seasons. Technologies such as hydroponics, vertical farming, aeroponics, polyhouse *etc*. brought additional benefits of regulating pests and diseases, thus reducing use of pesticides, apart from controlling weather conditions. Though in India, weather extremities (as that of temperate regions) are generally not seen, hydroponic cultivation is pursued in order to cater to the need of pesticide conscious consumers. This method, in addition, provides the advantage of precision farming. Though this method is being practiced in India since over a decade, studies analyzing its economic costs and returns are limited. Its marketing arrangement also stands to be distinct from those of traditionally grown GLVs, signifying the need for its study.

**Methodology**

India is one of the largest producers of GLVs globally, with an annual production of approximately 9.24 million metric tons (MMT) in 2020-21. According to the National Horticulture Board (NHB), the GLVs are cultivated in about 0.6 million hectares of land, majorly in Uttar Pradesh (14.7%), West Bengal (13.6%), Madhya Pradesh (8.7%) and Karnataka (4.1%), with major crops being palak, amaranth, methi, mustard greens, and moringa leaves. The major GLV producing districts in Karnataka are Bengaluru Urban & Rural, Chikkaballapura, Kolar and Tumakuru. These districts located surrounding Bangalore, despite dry land conditions (low rainfall and poor soil fertility), produce leafy vegetables in significant acreage. Further, these districts mostly comprise the Eastern Dry Zone of the state, where the present study is undertaken.

The EDZ accounts for 42.66 per cent of the total area under leafy vegetables, contributing 52.75 per cent to the state’s total production, with an average productivity of 12.89 mt/ha, exceeding the state average of 11.53 mt/ha (Anonymous, 2024). Bangalore (U), Kolar and Chikkaballapur has highest Methi area (19.83%) in Karnataka, producing 22.59 per cent of the state’s total. The productivity of Methi in these districts (13.47 mt/ha) is higher than the state’s average, and these regions contribute 17.83 per cent of the total value realized from Methi.

Palak cultivation is more concentrated in these districts, covering 61.23 per cent of the state's area under the crop and contributes 96.70 per cent to the production. The productivity of Palak (13.21 m t/ha) is significantly higher than the state average (10.58 m t/ha), and these districts generate 50.89 per cent of the total revenue from Palak. Overall, the share of these districts in total leafy vegetable production (54.08% of total value generated) indicates the economic significance of these crops.

Bengaluru Urban and Kolar districts emerge as major contributors of GLV production, while Tumakuru has a relatively smaller share. The EDZ of Karnataka being characterized by low average annual rainfall of 679 mm, semi-arid conditions make it suitable to grow water-efficient (as compared to other crop groups, because of short crop duration) crops like leafy vegetables. Bangalore city, housing 1/7th of the state’s population, is a major consumption centre providing scope for a wider cultivation of crop.

The Eastern Dry Zone of Karnataka is purposively selected for the study as it is the major producer as well as consumer of GLVs as it houses the state capital. Also, there are about 15-20 different GLVs that are being consumed. Of these coriander, methi, palak, curry leaves, amaranthus are more popular. The table 1 & 2 highlights Karnataka GLV production profile and the contribution of Eastern dry zone to state total. It is observed that 43 per cent of the state’s area under GLVs is covered in EDZ. In terms of production, a 53 per cent contribution; productivity also higher at 11.72 MT/ha, compared state average of11.53 MT/ha. Contribution of the zone to state GLVs value stood at 55 per cent.

**Table 1: Crop-wise Area, Production, Yield, and Value of Karnataka in 2021-22**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Crops** | **Area (Ha)** | **Production (M. Tons)** | **Yield (M.Tons/ha)** | **Value (Rs. in lakhs)** |
| Methi | 1160 | 13830 | 11.93 | 1346 |
| Palak | 833 | 8811 | 10.58 | 1128 |
| Amaranthus | 646 | 12490 | 19.33 | 3640 |
| Curry leaves | 618 | 3937 | 6.37 | 1072 |
| Other leafy vegetables | 6652 | 62772 | 9.44 | 7655 |
| **Total leafy vegetables** | **9909** | **101840** | **11.53** | **14841** |

Source: Directorate of Economics and Statistics, Department of horticulture, Government of Karnataka​, 2023

**Table 2: Area, Production, Yield, and Value of GLVs produced in Eastern dry zone of Karnataka in 2021-22**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **District** | **Area (Hectares)** | **Production (M. Tons)** | **Yield (M.Tons/ha)** | **Value (Rs. in lakhs)** |
| Bengaluru urban | 1042 | 21071 | 20.21 | 1874 |
| Bengaluru rural | 411 | 5596 | 13.61 | 3574 |
| Chikkaballapura | 387 | 3994 | 10.32 | 266 |
| Kolar | 2334 | 22490 | 9.64 | 2198 |
| Ramnagara | 26 | 151 | 5.81 | 97 |
| Tumakuru | 53 | 571 | 10.68 | 117 |
| **Total leafy vegetables (EDZ)** | **4253** | **53873** | **11.72** | **8126** |
|  **% contribution of GLVs from EDZ to state** | **42.92** | **52.90** | **-** | **54.75** |

Source: Directorate of Economics and Statistics, Department of Horticulture, Government of Karnataka​ 2023.

**Results & Discussion**

 This section presents and discusses economics of GLV production in open field and hydroponic cultivation separately. Later, the two are compared, for better understanding.

**Cost of palak production in open field**

Table 3 depicts the total cost of palak production in open-field condition to be Rs. 33,848, of which variable cost was 67 per cent; labour cost being single largest head (41.55%). Land preparation, sowing, plant protection, harvest and bundling activities engaged labourers. FYM (7.75%), machine labour (5.86%), seeds (4.86%), fertilizers (3.82%), plant protection chemicals (3.61%) (such as carbendazim@ 2g/ltr or mancozeb 75% wp) and Foliar spray of urea (1.5%) + GA3 (15 ppm), weedicides (1.11%) (pendimethalin and metribuzin) and irrigation charges (3.59%) were other variable cost items. It is to be noted surprisingly that even GLV production makes use of PPCs as well as growth regulators. It is more probable that it is consumed with residues because of obvious reasons, thus potentially increasing health concerns, while GLVs are consumed basically as natural and health booster. The fixed cost accounting to 32.94% of total, is mostly due to imputed rental value of land (29.68%).

**Table 3: Cost of palak cultivation in open field (per acre) *(n=36)***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl. No.** | **Particulars** | **Quantity** | **Cost (Rs.)** | **Share (%)** |
| **A** | **Labor costs** |
| 1 | Human labour (Man-days) | 30.20 | 12,080.00 | 35.69 |
| 2 | Machine labour (hrs) | 2.05 | 1,984.14 | 5.86 |
|  | **Total labour cost** | **-** | **14,064.14** | **41.55** |
| **B** | **Material costs** |
| 3 | Seeds (kgs) | 7.47 | 1,643.60 | 4.86 |
| 4 | FYM (t) | 2.68 | 2,622.27 | 7.75 |
| 5 | Fertilisers |
|  | 1. Urea (Kgs)
 | 35.13 | 210.79 | 0.62 |
|  | 1. DAP (Kgs)
 | 40.11 | 1,082.86 | 3.20 |
| 6 | PPC (PGR & fungicide) | - | 1,221.36 | 3.61 |
| 7 | Weedicide | - | 375.40 | 1.11 |
| 8 | Irrigation charges (Acre inch) | 4.9 | 1,215.20 | 3.59 |
|  | **Total material cost** | - | **8,371.48** | **24.73** |
| 9 | Interest on working capital@7% |  | 261.75 | 0.77 |
| **I** | **Total variable costs (TVC)** | - | **22,697.37** | **67.06** |
|   | **Fixed costs** |
| 1 | Depreciation costs | - | 856.33 | 2.53 |
| 2 | Land revenue | - | 30.00 | 0.09 |
| 3 | Rental value of land | - | 10,045.50 | 29.68 |
| 4 | Interest on fixed capital@12% | - | 218.64 | 0.65 |
| **II** | **Total fixed costs (TFC)** | - | **11,150.47** | **32.94** |
|   | **Total costs (TVC +TFC)** | - | **33,847.83** | **100.00** |

**Note:** FYM-Farm Yard Manure, PPC-Plant protection chemicals, PGR-Plant Growth Regulators.

**Cost of Fenugreek cultivation in open field**

Table 4 depicts the total cost of fenugreek cultivation stood at Rs.38,698. The variable costs, totalling to Rs.27,527 (71.13%), included various operational expenses. Labor costs added up to Rs.13,805 (35.67%), comprised of human labour (30.01%) and machine labour (5.43%). Material costs added up to Rs.13,404.99 (34.64%), with seeds (14.18%), FYM (9.82%), fertilizers (4.60%), plant protection chemicals (2.53%), weedicides (2.53%), and irrigation costs (3.08%) contributing to it. The fixed costs, totalling to Rs.11,170.97 (28.87%), include long-term expenses that remain constant regardless of production. The rental value of land is Rs.10,045.60 (25.96%), representing the opportunity cost of using the land for cultivation. Jawale *et al.* (2011) studied the economics of production and marketing of green leafy vegetables in the vicinity of parbhani district Maharashtra and found that the per hectare costs of palak and fenugreek were found to be Rs.69,373, and Rs. 53,344 respectively which is in similar to the results of the present study.

**Table 4: Cost of fenugreek cultivation (per acre) in open field *(n=36)***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl. No.** | **Particulars** | **Quantity** | **Cost (Rs.)** | **Share (%)** |
| **A** | **Labor costs** |
| 1 | Human labour (Man-days) | 29.05 | 11,620.00 | 30.03 |
| 2 | Machine labour(hrs) | 2.3 | 2,185.00 | 5.65 |
|  | **Total labour cost** | **-** | **13,805.00** | **35.67** |
| **B** | **Material costs** |
| 3 | Seeds(kgs) | 24.95 | 5,489.00 | 14.18 |
| 4 | FYM (t) | 3.8 | 3,800.00 | 9.82 |
| 5 | Fertilisers |
|  | 1. Urea (Kgs)
 | 33.49 | 200.93 | 0.52 |
|  | 1. DAP (Kgs)
 | 34.46 | 930.51 | 2.40 |
| 6 | PPC (PGR & fungicide) | - | 813.75 | 2.10 |
| 7 | Weedicide | - | 980.40 | 2.53 |
| 8 | Irrigation charges (Acre inch) | 4.8 | 1,190.40 | 3.08 |
|  | **Total material cost** | - | **13,404.99** | **34.64** |
| 9 | Interest on working capital@7% |  |  | 317.45 |
| **I** | **Total variable costs** | - | **27,527.44** | **71.13** |
|   | **Fixed costs** |
| 1 | Depreciation costs | - | 856.33 | 2.21 |
| 2 | Land revenue | - | 30.00 | 0.08 |
| 3 | Rental value of land | - | 10,045.60 | 25.96 |
| 4 | Interest on fixed capital@12% | - | 219.04 | 0.57 |
| **II** | **Total fixed costs** | - | **11,170.97** | 28.87 |
|   | **Total costs (TVC +TFC)** | - | **38,698.41** | **100.00** |

**Cost of coriander cultivation in open field**

Table 5 elaborates the cost of coriander cultivation to be Rs.41,090. The variable cost amounted to Rs.29,939 (72.86%). The labour costs worked out to Rs.13,971 (340%), comprising of human labour (29.21%) and machine labour (5%). Material costs (38%) include expenditure on FYM (13.63%), seeds (13.42%), fertilizers (3.46%), PPCs (3.36%), irrigation (3.25%) while weedicides (0.91%) was a meagre cost item.

**Table 5: Cost of Coriander cultivation (per acre) in open field** *(n=36)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl. No.** | **Particulars** | **Quantity** | **Cost (Rs.)** | **Share (%)** |
| **A** | **Labor costs** |
| 1 | Human labour (Man-days) | 30.01 | 12,004.00 | 29.21 |
| 2 | Machine labour(hrs) | 2.07 | 1,966.50 | 4.79 |
|  | **Total labour cost** | - | **13,970.50** | **34.00** |
| **B** | **Material costs** |
| 3 | Seeds(kgs) | 22.05 | 5,512.50 | 13.42 |
| 4 | FYM (t) | 5.60 | 5,600.00 | 13.63 |
| 5 | Fertilisers |  |
|  | 1. Urea (Kgs)
 | 44.98 | 314.83 | 0.77 |
|  | 1. DAP (Kgs)
 | 40.95 | 1,105.65 | 2.69 |
| 6 | PPC (PGR & fungicide) | - | 1,380.80 | 3.36 |
| 7 | Weedicide | - | 375.40 | 0.91 |
| 8 | Irrigation charges (Acre inch) | 5.38 | 1,334.24 | 3.25 |
|  | **Total material cost** | - | **15,623.42** | **38.02** |
| 9 | Interest on working capital@7% |  | - | 345.26 |
| **I** | **Total variable costs** | - | **29,939.18** | **72.86** |
|   | **Fixed costs** |
| 1 | Depreciation costs | - | 856.33 | 2.08 |
| 2 | Land revenue | - | 30.00 | 0.07 |
| 3 | Rental value of land | - | 10,045.60 | 24.45 |
| 4 | Interest on fixed capital@12% | - | 218.64 | 0.53 |
| **II** | **Total fixed costs** | - | **11,150.57** | **27.14** |
|   | **Total costs (TVC +TFC)** | - | **41,089.75** | **100.00** |

The fixed costs for coriander cultivation totalled to Rs.11,151 making up to 27.14 per cent of the total cost. While depreciation cost (2.08%), interest on fixed capital (0.53%) and land revenue (0.07%) were meagre, the rental value of land (24.45%) was substantial. The above results are similar to the study conducted by Anil in 2009 at Mahatma Phule Krishi Vidyapeeth, Rahuri. The study found the average per acre total cost of cultivation for coriander was Rs.32,010.99. The major items of cost were rental value of land, manure and bullock labour.

**Comparison of yield and returns of selected GLVs production in open field**

Table 6 presents the summary of yield, price, gross and net returns, return per rupee of expenditure and cost of production of the selected GLVs in study area. The average yields of palak, coriander and fenugreek were found to be 26.18, 30.41 and 27.60 quintals per acre respectively, with average prices of Rs. 20.92, Rs.25.86, and Rs.26.07 per kg, which leads to the gross income of Rs.59,344, Rs.71,383 and Rs.79,271 respectively. The returns per rupee of expenditure was found to be Rs. 1.75, Rs. 1.84 and Rs.1.93 respectively and cost of production per kg of production in palak, fenugreek and coriander amounted to Rs. 11.93, Rs. 14.02 and Rs. 13.51. These results are in agreement with results of Satpute *et al*., (2009) who studied the economics of production of leafy vegetables in Marathwada region of Maharashtra reported that input output ratio obtained for palak was 1:1.55, while for methi it was 1:1.59 indicating growing of leafy vegetables under study to be profitable.

The fig.1 pictorially depicts the results. Though coriander production incurred higher cost, because of its higher price (Rs.26.07/kg) as well as yield (3 tonnes), its gross and net returns were the highest. Palak, despite the lowest of cost, lower market price (Rs.20.92/kg) dragged its gross and net returns to be lowest. However, Palak crop observed a lowest production cost of Rs. 11.93/kg. It would be interesting to note that per kg profit stood the highest among coriander at Rs. 13, about Rs. 11 in case of fenugreek and the lowest of Rs. 9 in case of palak.

**Table 6: Yield and returns of palak, fenugreek and coriander in open field** *(n=36)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl. No.** | **Particulars** | **Palak** | **Fenugreek** | **Coriander** |
| 1 | Total cost of cultivation (Rs./acre) | 33,847.83 | 38,698.41 | 41,089.75 |
| 2 | Yield (Kgs\*/acre) | 2,836.72 | 2,760.37 | 3,040.69 |
| 3 | Price (Rs/kg) | 20.92 | 25.86 | 26.07 |
| 4 | Gross returns (Rs./acre) | 59,344.20 | 71,383.06 | 79,270.72 |
| 5 | Net returns (Rs./acre) | 25,496.36 | 32,684.65 | 38,180.98 |
| 6 | Returns per rupee of expenditure | 1.75 | 1.84 | 1.93 |
| 7 | Cost of production (Rs./kg) | 11.93 | 14.02 | 13.51 |

**Fig.1**: **Comparison of cost, returns and yield among three crops in open field**

**Effect of price fluctuation on returns**

 The above cost-return analysis considered average prices of produce, while a wide variation in its price was witnessed during the study period, owing to changes in demand and supply. A look at the impact of changes in farmers income with the minimum and maximum price is projected in table 7. Palak price ranged from Rs.3.05 to Rs.38.80 per kg, with an average price of Rs.20.92 per kg and an average yield of 2,8kgs/acre. The gross returns at maximum price are Rs.1.1 lakh/acre, while at minimum price, it drops to Rs 8,652/acre. Net returns ranged from a loss of Rs.25,195 at the lowest price to a profit of Rs.76,216 at the highest price, showing a moderate profitability with adjoining potential risks.

Coriander price ranged from Rs.2.53 to Rs.50.61/kg (indicating high price dispersion) and an average price of Rs.26.07 per kg. Its gross returns could reach Rs.1,53,889 at the maximum price and Rs.7,692 at minimum price. Net returns varied from a loss of Rs.31,005 to a profit of Rs.1.15 lakh, and substantial profit potential. Fenugreek price ranged from Rs.7.86 to Rs.43.86/kg, averaging at Rs.25.86/kg. Gross returns stood at Rs.1.21 lakh at the maximum price and Rs.21,696 at the minimum. Net returns fluctuate from a loss of Rs.19,393 to a profit of Rs.79,979, presenting moderate risk and returns.

**Table 7: Effect of price fluctuation on GLV returns**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Price (Rs. /Kgs)** | **Total cost** | **Average yield (Kgs /acre)** | **Gross returns @ Max. price** | **Gross returns @min. price** | **Net returns @minimum price** | **Net returns @maximum price** |
| **Crop** | **Maximum** | **Average** | **Minimum** |
| Palak | 38.80 | 20.92 | 3.05 | 33,847 | 2,836 | 1,10,064 | 8,652 | -25,195 | 76,216 |
| Coriander | 50.61 | 26.07 | 2.53 | 41,089 | 3,040 | 1,53,889 | 7,692 | -31,005 | 1,15,190 |
| Fenugreek | 43.86 | 25.86 | 7.86 | 38,698 | 2,760 | 1,21,069 | 21,696 | -19,393 | 79,979 |

**Costs and returns of GLV production in hydroponic system**

**Establishment cost of hydroponic structure**

As against open field cultivation, GLV production in hydroponic system incurs a substantial investment, hence not affordable to resource poor farmers. A considerable awareness of technology and its use is a must for this method. Higher returns are anticipated in this system, due to niche market, growing demand and high crop intensity, supporting continuous production cycles. Table 8 outlines the total establishment cost of the hydroponic structure for the cultivation of GLVs in protected polyhouse setup of one acre (43,560 square feet). The summary of quantities of various components, costs per unit, total value, useful life and the amortized annual cost (at 12 per cent interest rate) is presented in table 8. The major costs in hydroponics is the poly house structure which is around Rs.21.78 lakhs with an annual amortized cost (8 years of economic life) of Rs. 2.61 lakhs. The shade net for the same area costs around Rs.5.23 lakhs with a five-year useful life and an annual amortized cost of Rs 1.45 lakhs, followed by the investment on drip irrigation structures - NFT, which is the most important part of the hydroponic structure. It incurred a cost of Rs.13.07 lakhs, with eight year useful life and an annual amortized cost of Rs.1.57 lakhs.

Two electric pumps are required for the functioning of one-acre hydroponic unit which costs Rs 0.96 lakh and amortized cost of Rs.23,349.67is accounted considering a useful life of six years. Six water storage tanks are required for the supply of water through the irrigation structures which incurs a cost of Rs. 0.56 lakhs with eight-year useful life and an annual amortized cost of Rs. 11,232.92. The minor investments on pH meters which costs around Rs. 12,000 with a five-year life span calculates to an annual amortized value of Rs. 3,328.92. With a need to control the external environmental conditions, for which investment on micro climate control machines like fans costs around Rs.1.08 lakhs followed by heaters to maintain the suitable temperatures required for the specific crop costs around Rs.1.2 lakhs accompanied by temperature monitors costing around Rs.0.5 lakhs. The humidity sensors cost Rs.0.31 lakhs over a six years useful life. The annual amortized costs of fans, heaters, temperature monitor and humidity sensors amounted to Rs.26,268.38, Rs.29,187.09, Rs.12,258.58, and Rs.7,588.64, respectively. The total establishment cost for the hydroponic structure is Rs.44.81 lakhs, which accounted for amortized annual cost of Rs.6.76 lakhs. Similar initial establishment costs of hydroponic unit were recorded by Kaveri (2021) highlighting significant variations investment, cost structures, and financial viability across different farm sizes and crop choices. The study observed eight hydroponic farms, predominantly adopting the NFT system, which is widely used for cultivating lettuces (romaine, butter head, batavia, and leaf), basil, kale, and other leafy vegetables i.e., the total initial investment cost ranged between Rs. 4.28 lakhs to 2.07 crores.

Since the same unit is used for production of different crops in different sections, the annual amortized fixed cost would remain the same for all. Thus, the fixed cost remains the same for the three crops under consideration. It is to be noted however that the one acre setup is not completely used for any single crop, while different crops are produced in batches depending on demand pattern. Hence, the computations are based on assumption that each of the crops are grown in one acre setup.

**Table 8: Establishment cost of hydroponic unit in polyhouse in one-acre for GLV production and its amortized value** *(n=14)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Particulars** | **Quantity** | **Cost****(Rs./Unit)** | **Value (Rs.)** | **Useful life****(Years)** | **Amortised****annual****cost @ 12%** |
| Polyhouse structure/frame (s.f.) | 43,560 | 50 | 21,78,000.00 | 8 | 26,1359.00 |
| Polyhouse shade net (s.f.) | 43,560 | 12 | 5,22,720.00 | 5 | 14,5007.62 |
| Electric pumps (No.) | 2 | 48,000 | 96,000.00 | 6 | 23,349.67 |
| Water storage tanks (No.) | 6 | 9,300 | 55,800.00 | 8 | 11,232.70 |
| pH meters (No.) | 3 | 4,000 | 12,000.00 | 5 | 3,328.92 |
| Climate control machines |  |  |  |  |  |
| A) Fans (No.) | 18 | 6,000 | 1,08,000.00 | 6 | 26,268.38 |
| B) Heaters (No.) | 8 | 15,000 | 1,20,000.00 | 6 | 29,187.09 |
| C) Temperature monitors (No.) | 12 | 4,200 | 50,400.00 | 6 | 12,258.58 |
| D) Humidity sensors (No.) | 6 | 5,200 | 31,200.00 | 6 | 7,588.64 |
| Drip irrigation systems (s.f.) | 43,560 | 30 | 13,06,800.00 | 8 | 1,56,815.00 |
| **Total establishment cost** |  |  | **44,80,920.00** |  | **6,76,395.58** |

***Note:*** *NFT refers to the nutrient film technique which is the irrigation method followed in hydroponic unit****s.***

**Cost of palak production in hydroponic cultivation**

The details of cost of palak cultivation in on acre hydroponic system is presented in Table 9. Among the variable costs, labour charges emerge as the highest expense of Rs.14,800/acre (10.6%). Labour is utilized right from cleaning/sterilizing of plant holders and in production system, *viz.*, adding nutrients to NFT systems, harvesting, packing, loading/unloading, marketing etc. Electricity costs amounted to at Rs.10,175 per acre (7.29%), requirement for maintenance of controlled environment for the plant growth depicting energy intensiveness. Nutrient solutions, *viz.*, nitrogen, phosphorus, potash, and micronutrients, comprise a cost of Rs.14,100 per acre (10.09%), signifying their crucial role.

**Table 9: Cost of palak production (per acre, per production cycle) in hydroponic system**

*(n=14)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SI. No.** | **Particulars** | **Price (Rs./unit)** | **Quantity** | **Value (Rs/acre)** | **Share (%)** |
| 1 | Seed cost (Kgs) | 300 | 8 | 2,400.00 | 1.72 |
| 2 | Nutritional and fertilizers solutions |
|  | A) Nitrogen (Litres) | 90 | 45 | 4,050.00 | 2.90 |
|  | B) Phosphorous (Litres) | 120 | 30 | 3,600.00 | 2.58 |
|  | C)Potash (Litres) | 150 | 25 | 3,750.00 | 2.68 |
|  | D)Micro nutrients (Litres) | 180 | 15 | 2,700.00 | 1.93 |
| 3 | Electricity cost (Units) | 18.5 | 550 | 10,175.00 | 7.29 |
| 4 | Sterilisation and cleaning chemicals (Litres) | 700 | 4.5 | 3,150.00 | 2.26 |
| 5 | Labor cost (wages and salary) | 550 | 37 | 14,800.00 | 10.60 |
| 6 | Marketing costs (Trays) | 3.5 | 700 | 2,450.00 | 1.75 |
| 7 | Interest on working capital @7% | - | - | 411.91 | 0.29 |
| A | **Total variable costs** | **-** | - | **47,486.91** | **34.00** |
| 1 | Amortised establishment cost\* | - | - | 84,549.45 | 60.54 |
| 2 | Rental value of land | - | - | 7,500.00 | 5.37 |
| 3 | Land revenue | - | - | 18.75 | 0.01 |
| 4 | Interest on fixed capital@12% | - | - | 112.78 | 0.08 |
| B | **Total fixed cost** | **-** | - | **92,180.98** | **66.00** |
|  | **Total cost (A+B)** | **-** | - | **1,39,667.89** | **100.00** |

**Note:** \* Initial total establishment cost of hydroponic unit is taken and amortized through its useful life and is further calculated by dividing number of crops (*i.e.*, 8 crops) per year, to obtain cost/crop cycle.

Additionally, seed costs amount to Rs.2,400 (1.72%). Sterilization and cleaning chemicals *viz.*, bleaching powder and hydrogen peroxide which ensures disease free plant growth environment accounts to Rs.3,150 (2.26%) to maintain optimal hygiene. Marketing costs, primarily incurred on trays and packing, handling etc contribute Rs.2,450 (1.75%), while interest on working capital adds Rs.411.91 (0.29%). The total variable cost sums up to Rs.47,486.91 (34%). The operational expenses in hydroponic farming are driven mainly by labour, electricity and plant nutrients. Despite automation in production, there is requirement of labour for sterilization, transplanting, harvesting, and packing activities.

The major cost component in hydroponic farming is the fixed costs which constitutes Rs. 92,180.98 (66%), of which amortized establishment cost Rs. 84,549.45 (48.96%) computed from table 8 above. The rental value of land accounts for Rs. 7,500 (5.37%). The total cost of hydroponic palak cultivation per acre, per production cycle stands at Rs.1,39,667.89, depicting the capital-intensive nature of hydroponic farming. As compared to open field cultivation, the production cost of palak is 4 times higher.

**Cost of fenugreek production in hydroponic cultivation**

The detailed analysis of the cost of cultivating fenugreek in a one-acre hydroponic system is presented in Table 10. The total cost of fenugreek hydroponic cultivation per acre amounts to Rs.1,48,172, with variable costs contributing 37.79% and fixed costs accounting for 62.21%. Among the major variable costs, labour expenses stood highest, totalling to Rs.19,250 (13%), reflecting the wages and salaries required for managing the cultivation process. Electricity costs also form a significant share at Rs.10,730 (7.24%). Nutrient and fertilizer solutions, including nitrogen, phosphorus, potash, and micronutrients, collectively add up to Rs.16,950 (11.44%). Other variable costs include seed cost of Rs.4,200 (2.83%) and marketing expenses of Rs.2,275 (1.54%).

**Table 10**: **Cost Fenugreek production (per acre, per production cycle) in hydroponic system** *(n=14)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SI. No.** | **Particulars** | **Price****(Rs./Unit)** | **Quantity** | **Value (Rs/acre)** | **Share (%)** |
| 1 | Seed cost | 350 | 12 | 4,200.00 | 2.83 |
| 2 | Nutrient and fertilizers solutions |
|  | A) Nitrogen (Litres) | 90 | 50 | 4,500.00 | 3.04 |
|  | B) Phosphorous (Litres) | 120 | 35 | 4,200.00 | 2.83 |
|  | C) Potash (Litres) | 150 | 25 | 3,750.00 | 2.53 |
|  | D) Micro nutrients (Litres) | 180 | 25 | 4,500.00 | 3.04 |
| 3 | Electricity cost (Units) | 18.5 | 580 | 10,730.00 | 7.24 |
| 4 | Sterilisation and cleaning chemicals (Litres) | 700 | 3 | 2,100.00 | 1.42 |
| 5 | Labor cost (wages and salary) | 550 | 35 | 19,250.00 | 12.99 |
| 6 | Marketing costs (Trays) | 3.5 | 650 | 2,275.00 | 1.54 |
| 7 | Interest on working capital @7% | - | - | 485.67 | 0.33 |
| **A** | **Total variable costs** | **-** | - | **55,990.67** | **37.79** |
| 1 | Amortised establishment cost | - | - | 84,549.45 | 57.06 |
| 2 | Rental value of land | - | - | 7,500.00 | 5.06 |
| 3 | Land revenue | - | - | 18.75 | 0.01 |
| 4 | Interest on fixed capital@12% | - | - | 112.78 | 0.08 |
| **B** | **Total fixed cost** | **-** | - | **92,180.98** | 62.21 |
|  | **Total cost (A+B)** | **-** | - | **1,48,171.65** | 100.00 |

Of the fixed costs, which make up the majority (62.21%) of the total expenditure, amortized establishment cost is the highest at Rs.84,549.45 (57.06%), The rental value of land is Rs.7,500 (5.06%).

**Costs of coriander in hydroponic cultivation**

Table 11 elaborates coriander production costs and their shares under hydroponic system. The total cost stands at Rs.1,50,154, with the variable cost contributing 38.61 per cent and fixed costs accounting for 61.39 per cent. Among variable costs, labour expenses are the highest at Rs.19,250 (12.82%), covering wages and salaries. Electricity cost amounts to Rs.11,470 (7.64%), reflecting the energy consumption for running the hydroponic system. Nutrition and fertilizer solutions costing Rs.17,550 (11.7%). Additionally, seed costs stand at Rs.3,600 (2.40%), and sterilization and cleaning chemicals adds uptoRs.3,500 (2.33%).

**Table 11: Cost of coriander production *(per acre, per production cycle)* in hydroponic system** *(n=14)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Particulars** | **Price****(Rs./ Unit)** | **Quantity** | **Value (Rs./acre)** | **Share (%)** |
| 1 | Seed cost | 300 | 12 | 3,600.00 | 2.40 |
| 2 | Nutrition and fertilizers solutions |  |
|  | A) Nitrogen (Litres) | 90 | 60 | 5,400.00 | 3.60 |
|  | B) Phosphorous (Litres) | 120 | 40 | 4,800.00 | 3.20 |
|  | C) Potash (Litres) | 150 | 25 | 3,750.00 | 2.50 |
|  | D) Micro nutrients (Litres) | 180 | 20 | 3,600.00 | 2.40 |
| 3 | Electricity cost (Units) | 18.5 | 620 | 11,470.00 | 7.64 |
| 4 | Sterilisation and cleaning chemicals (Litres) | 700 | 5 | 3,500.00 | 2.33 |
| 5 | Labor cost (Manpower day) | 550 | 35 | 19,250.00 | 12.82 |
| 6 | Marketing costs (Trays) | 3.5 | 600 | 2,100.00 | 1.40 |
| 7 | Interest on working capital @7% | - | - | 502.86 | 0.33 |
| **A** | **Total variable costs** | **-** | - | **57,972.86** | **38.61** |
| 1 | Amortised establishment cost | - | - | 84,549.45 | 56.31 |
| 2 | Rental value of land | - | - | 7,500.00 | 4.99 |
| 3 | Land revenue | - | - | 18.75 | 0.01 |
| 4 | Interest on fixed capital @12% | - | - | 112.78 | 0.08 |
| **B** | **Total fixed cost** | **-** | - | **92,180.98** | **61.39** |
|  | **Total cost (A+B)** | **-** | - | **1,50,153.84** | **100.00** |

The fixed costs include the amortized establishment cost amounting to Rs.84,549.45 (56.31%) followed by rental value of land is Rs.7,500 (4.99%), accounting for land leasing expenses, land revenue ofRs.18.75 (0.01%) and interest on fixed capital at Rs.112.78 (0.08%), these minor costs have a negligible impact. The overall cost structure indicates that hydroponic farming requires high initial investment. However, the system offers the potential for higher productivity and resource efficiency.

**Comparison of yield, returns and price of GLV in hydroponic cultivation**

Table 12 and Fig.2 compares the economics of palak, fenugreek, and coriander production under hydroponic cultivation per acre, per production cycle. The total cost of cultivation per acre is highest in coriander production at Rs.1.50 lakh, followed by fenugreek Rs.1,48,171.65 and palak (Rs.1,39,667.89). Palak being a crop with relatively thick and big foliage it has highest yield 8,400 kgs per acre, followed by fenugreek (6,400 kgs) and coriander (6,200 kgs). This yield advantage for palak which is due to its adaptability and suitability to hydroponics translates into higher gross returns of Rs.4.2 lakh/acre, followed by Rs.4.03 lakh/acre and Rs.3.84 lakh/acre in case of coriander and fenugreek respectively. There was a considerable difference in price of hydroponic grown GLVs *viz.*, Rs. 50/kg for palak Rs.60/kg for fenugreek and coriander was sold at Rs. 65/kg. The prices were fixed for certain duration of time and revised periodically.

**Fig.2: Comparison of costs, returns and yield among 3 crops in hydroponic system**

When it comes to profitability, palak leads with a net return of Rs. 2,80,332.11 per acre, per production cycle, outperforming coriander (Rs. 2.53 lakh) and fenugreek (Rs.2.36 lakh).The returns per rupee of expenditure is also highest for palak at 3.01, indicating its superior cost-efficiency compared to coriander (2.68) and fenugreek (2.59). It is imperative that though fenugreek and coriander command higher market prices, palaks lower unit costs combined with higher yields make it the most profitable crop in hydroponic systems. Overall, palak presents a more favourable balance of input costs and output returns, making it a more economically viable option for hydroponic cultivation compared to fenugreek and coriander, despite the latter market price advantages. The results are similar to the as obtained from the Mishra, *et al.* (2024) who studied the economic viability of hydroponic farming: a comparative cost-benefit analysis comparative economics of lettuce. The findings showed that, for all three crops, the overall cost of crop cultivation in hydroponic was more than that of crop cultivation in open fields. For the lettuce cultivated in hydroponic condition, the percentage of total variable costs was greater than 65 per cent. Growing crops in hydroponics resulted in net returns that were more than twice as high, indicated that growing crops in polyhouses could be profitable. Again, returns per rupee were greater for lettuce.

**Table 12**: **Yield and returns of all three leafy vegetables in Hydroponics**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SI. No.** | **Particulars** | **Palak** | **Fenugreek** | **Coriander** |
| 1 | Total cost of cultivation (Rs. / acre) | 1,39,667.89 | 1,48,171.65 | 1,50,153.84 |
| 2 | Yield (Kgs\*/acre) | 8,400.00 | 6,400.00 | 6,200.00 |
| 3 | Price (Rs/kg) | 50.00 | 60.00 | 65.00 |
| 4 | Gross returns (Rs. / acre) | 4,20,000.00 | 3,84,000.00 | 4,03,000.00 |
| 5 | Net returns (Rs. / acre) | 2,80,332.11 | 2,35,828.35 | 2,52,846.16 |
| 6 | Returns per rupee of expenditure | 3.01 | 2.59 | 2.68 |

Fig. 3 presents the comparison of costs and returns of open field and hydroponic grown green leafy vegetables. The cost incurred per acre, per production cycle for all the three (palak, fenugreek and coriander) crops in hydroponics was over thrice that of open field. The comparative returns among hydroponic systems generally exceeded more than three times, thus yielding 4-5 times more net returns in hydroponic system.

**Fig. 3: Comparison of cost and returns of GLV in open field and hydroponics**

**Conclusion**

 GLVs take a special place in both producer and consumption basket of Indian consumers, perceived to be of healthy, nutritious, fresh produce with lots of fibers. Benefitting the producers too, this 30-35 days crop shall yield returns, requiring least crop care and operations and hence lower costs when grown in open field. Contrarily, high income consumer group with western exposure and health consciousness prefer exotic GLVs grown in hydroponic system. GLVs of these two systems are grown and consumed by different groups. An economic analysis is the crux of this paper.

 A total cost of Rs. 32, 38, 41 thousand was incurred on producing palak, fenugreek and coriander in open field, of which close to 30% was fixed cost. one-third of the total is incurred on human labour. Producing every one kg of these crops incurred a cost of Rs. 11.93, Rs. 14.02 and Rs. 13.51 respectively and returns per rupee of expenditure was found to be Rs. 1.75, Rs.1.93 and Rs.1.84 respectively. However, since open field grown GLVs are sold in conventional markets, prices fluctuate with production & supply aberrations while its demand is generally constant. For Palak, fenugreek and coriander, the price ranged from Rs. 3-38, Rs. 7-43 and Rs. 2-50 respectively. While upper end price always increased profits, the bottom end produced losses ranging from Rs. 19-31 thousand for these crops which is unwelcome for producers. However, such peak or plunge prices are evidenced rarely.

 While open field GLV farmers were small & marginal holders while hydroponic units were owned by wealthy and educated class. Hydroponic unit demands an investment of Rs. 45-50 crore for one acre establishment, working out to an annual amortized value of Rs. 6.75 lakhs. However, it may vary by the size and technology adopted as evidenced by Kaveri (2021). Cost of cultivating GLVs was higher by 3-4 times for hydroponics compared to open field. But gross returns scaled up by 5-7 times and net returns by 6-11 times. The former issold in local/traditional marketing channels at lower market price (Rs. 20-25/kg) while the latter through exclusive marketing channels attracted double the price (Rs.60-70/kg). The yield also was higher by 2-3 times.

 Though GLVs are lauded for its nutritive pride, presently use of chemicals in both systems is a matter of concern. A few decades ago, GLVs were grown free of chemicals, however, we don't get any farm produce raised without chemical inputs, including GLVs. Both production systems use chemicals. In open field pest, disease and weed control require chemicals while it was chemical nutrients in hydroponic units. The latter can reduce chemical nutrients as bio-nutrients are now-a-days available in the market. Producing even GLVs without PPCs could be a dream, as farmers are totally habituated to its use. In fact open field GLV growers seem to have standardized their production protocols with preventive chemical use, thus transforming even the nutrition lauded GLVs studded with potentially harmful chemicals.

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