



RESEARCH ARTICLE

Comparative economic analysis of cucumber under different protected structures

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Abstract

An economic analysis was conducted to assess cucumber production under different protected structures naturally ventilated polyhouses (NVPH), net houses and walk-in tunnels in Sonapat, Karnal and Hisar districts of Haryana. The study revealed notable differences in profitability and efficiency across districts and structures. NVPH cultivation was most profitable in Sonapat, which also exhibited the highest benefit-cost ratio, followed by Karnal and Hisar. In net houses, Karnal outperformed the other districts in both net returns and benefit-cost ratio, with Sonapat ranking second and Hisar third. For walk-in tunnels, Sonapat again recorded the highest net returns and benefit-cost ratio, while Hisar showed comparatively lower profitability. These findings suggest that district-specific and structure-specific management practices have a significant impact on economic outcomes in cucumber cultivation. The marketing analysis highlighted that the share of the consumer's rupee reaching the producer varied across districts. Channel III, which involves direct sales from producer to consumer, was most beneficial in Hisar, allowing producers to capture a larger share, followed by Sonapat and Karnal. Overall, the study emphasizes the importance of selecting appropriate protected structures based on district conditions and marketing channels to maximize returns and efficiency in cucumber production.

Keywords: B:C ratio; comparative; cucumber; economics; protected structures

Introduction

The Indian economy is reliant on the agricultural sector, with a significant proportion of the residents in rural regions, particularly over 58 %, relying on agriculture as their main source of income (1). Since the start of the green revolution in India, there has been a heightened focus on both the quantity and quality of agricultural output to meet the growing need for sustenance and nutrition. Some of the regions are not only harsh conditions but also inaccessible, making it impossible to conduct typical agricultural activities there. Greenhouse agriculture might be the solution to the problem of how to meet the requirements of the people living in inaccessible regions. In the regions around towns and villages, there is a huge need for fresh vegetables. The main objective of protected agriculture is to provide a conducive environment that enables the crop to reach its maximum potential, even in the face of negative environmental conditions (2).

We need to use modern farming methods, like growing crops in protected structures, because of rising population demands, climate change, shrinking land holdings, pressure on natural resources, concerns about land and water quality and the demand for high-quality fresh fruits and vegetables. Protected vegetable farming provides farmers with clear benefits in terms of

product quality, output and advantageous market values. Seasonality and temperature have a big impact on the output of vegetables and flowers. The volume of their output results in significant price and quality changes for veggies. A significant challenge for the application of contemporary agricultural production technology is finding a compromise between a year-round supply of vegetables and flowers with minimal environmental effects while remaining competitive (2). Protected gardening, one of the productivity-enhancing technologies, has enormous potential to boost vegetative and floral produce yields. In India, controlled agriculture has seen a sharp increase in agricultural output. Compared to open vegetable cultivation, polyhouse cultivation can yield up to twice (3). The main fruits produced in India under various protective structures are tomato, pepper, cucumber, rose, daisy, carnation and chrysanthemum. The area under protected structures was less during the period of 2010-11 because of the high cost of structures and lack of knowledge (4 - 6). During the period of 2012-13 and 2013-14, the adoption of protected structures was higher because of the training programmes conducted by the concerned departments in the state.

The cucumber, scientifically known as *Cucumis sativus* L. and referred to as *khira* in Hindi, is a popular summer vegetable that is produced all over India. The temperature range of 18 °C to 24 °C is optimal for cucumber growth. Cucumbers are typically grown during mild seasons. This fruit matures in only 90 - 100 days after planting. According to the Ministry of Agriculture and Farmers' Welfare of the Government of India, the overall area under cucumber agriculture in India during the 2017-2018 fiscal year was 0.08 million hectares and the country produced 1.26 million tons of cucumbers. Both the area and production of cucumbers grown in open fields in Haryana during the 2018-19 growing season were estimated to be 0.02 million hectares and 0.24 million tonnes, respectively. On the other hand, the area and production of cucumbers grown in protected fields in Haryana were estimated to be 0.5 thousand hectares and 33000 tonnes, respectively.

The region of origin of cucumbers is Southern Asia, but today they are cultivated in almost every country. In Haryana, greenhouses were used to cultivate cucumbers almost continuously throughout the entire year. In greenhouse structures, it was discovered that the harvesting efficiency of cucumber cultivation was greater than 200 %. Cucumbers can be cultivated in all kinds of soil, from shallow soil to heavier soil, but the soil types of clay loam, loam and silt loam are considered to be the best for producing the highest yields. Both the Multistar and the Hiltan varieties of cucumber were cultivated in protected structures (7). Because of the ever-increasing demand for cucumbers produced through protected cultivation, more farmers are becoming interested in growing cucumbers in greenhouses during the offseason. This is due to the fact that greenhouse-grown cucumbers have both a quantitative and a qualitative advantage over those produced through traditional cultivation (8). Greenhouse technology has the potential to be a game-changer for environmentally responsible agricultural production and for achieving food security in areas that are struggling with problems of food shortage. (i.e., fruits and vegetables). It not only ensures an increase in food production but also boosts the overall productivity (9). The present study undertook an economic analysis of cucumber cultivation under protected structures in Haryana. The primary purpose of the research is to assess the benefit-cost relationship for a variety of different types of protected structures.

Materials and Methods

The current study was conducted in Haryana with the aim of carrying out an economic analysis of cucumber cultivation under protected structures. For the collection of primary data, multistage purposive sampling was used. The selection of Sonapat (28.9931° N, 77.0151° E), Karnal (29.6857° N, 76.9905° E) and Hisar (29.1492° N, 75.7217° E) districts was deliberate due to their abundance of diverse protected structures, such as naturally ventilated polyhouses, net houses and walk-in tunnels. Two blocks from each district were selected based on the presence of all types of protected structures and predominance in vegetable cultivation under these structures. 30 respondents were purposively selected from each block, thus making a total sample of 180 respondents. When compiling the cost structure, returns and earnings, the tabular presentation was chosen as the format. Calculations of averages and percentages, along with other statistical tools, were performed in order to analyse and understand the findings. The cost of cultivation under protected structures includes all annual expenses incurred for their maintenance, categorized into variable and fixed costs. The costs

associated with materials, seed, fertilizers, plant protection and interest on working capital at a rate of 9 % were the things that were considered changeable costs (prevailing lending rate). The leasing worth of property, as well as amortisation and transportation costs, are included in the category of fixed costs. The values of the overall quantity of cucumbers generated are multiplied by the amounts at which the product is sold to arrive at the gross profits. To calculate the benefit-cost ratio, we first took the total profits from a unit and divided them by the total expenses of a unit. We have gathered information about the prices and expenses of marketing from the closest market in each of the districts. For the purpose of the research, these marketplaces were specifically chosen. Using the Acharya method (10), the Shepherd method (11) and the conventional method, researchers were able to determine the marketing effectiveness of various marketing platforms.

Results and Discussion

Initial investment in a protected structure

Respondent farmers from selected districts of Haryana provided information on the investments made in different types of protected structures. The costs varied across structures, with NVPH being more expensive than net houses and walk-in tunnels. The National Horticulture Mission (NHM), implemented by the Department of Horticulture, Government of Haryana, provides subsidies for establishing protected structures 50 % for all farmers and 65 % for those with landholdings of less than 2 hectares.

The study found that the total cost of constructing an NVPH over one hectare (10000 m²) was ₹8203886/ha, of which producers contributed ₹3491386 while the government subsidy covered ₹4712500. A related study estimated the construction cost of a polyhouse in Tamil Nadu at around ₹38.74 lakhs per 4000 m² (12). Similarly, the initial capital requirement for constructing a net house over one acre was ₹5667895, including a government grant of ₹3087500 and a producer's contribution of ₹2580395 (13). For a one-hectare walk-in tunnel, the total expenditure was estimated at ₹5732836, with ₹4810000 provided as a subsidy and ₹922836 contributed by farmers (14).

The initial cost of irrigation infrastructure was similar across all protected structures. The total cost incurred for irrigation facilities was ₹63000, of which 50 % (₹31500) was subsidized by the government, leaving the remaining 50 % (₹31500) to be borne by the farmers.

Cost and return from cucumber cultivation under a naturally ventilated polyhouse

This section explains the results of a comparative economic study on cucumber cultivation under NVPH structures in selected districts of Haryana. Table 1 presents the variable costs, total costs and various components of returns.

The analysis shows that the highest total cost of cucumber cultivation per hectare was incurred in Sonapat district (₹708912/ha), followed by Karnal (₹693658/ha) and Hisar (₹67,845/ha). Among the components of total cost, the largest share was attributed to variable costs, with Sonapat recording the highest (₹322819/ha), followed by Karnal (₹308559/ha) and Hisar (₹306395/ha). Rental value of land varied across districts, being the highest in Karnal (₹41167/ha), followed by Sonapat (₹36021/ha) and Hisar (₹25729/ha). The higher rental value in Karnal was linked to the prevailing rice

Table 1. Cost and returns of cucumber cultivation under NVPH in Haryana (₹/ha)

Particulars	Hisar	Karnal	Sonepat	Haryana
Preparatory tillage	7234 (1.07)	7297 (1.05)	7021 (0.99)	7184 (1.04)
Ridging/ Bed preparation	7586 (1.13)	7416 (1.07)	8056 (1.14)	7686 (1.11)
Seedling cost	146789 (21.78)	143594 (20.7)	148529 (20.95)	146304 (21.14)
Gap filling	10445 (1.55)	12365 (1.78)	13662 (1.93)	12157 (1.76)
Total fertilizer cost	28412 (4.22)	30123 (4.34)	29197 (4.12)	29244 (4.23)
Hoeing, Weeding and stacking	11397 (1.69)	11747 (1.69)	13131 (1.85)	12092 (1.75)
Cost of pesticide	16090 (2.39)	15020 (2.17)	16598 (2.34)	15903 (2.30)
Harvesting/picking	53987 (8.01)	55652 (8.02)	60883 (8.59)	56841 (8.21)
Irrigation	4411 (0.65)	5160 (0.74)	4623 (0.65)	4731 (0.68)
Variable cost	286350 (42.49)	288373 (41.57)	301700 (42.56)	292141 (42.21)
Interest on working capital (7 %)	20045 (2.97)	20186 (2.91)	21119 (2.98)	20450 (2.95)
Total variable cost	306395 (45.47)	308559 (44.48)	322819 (45.54)	312591 (45.16)
Management charges (10 %)	30639 (4.55)	30856 (4.45)	32282 (4.55)	31259 (4.52)
Risk Factor (10 %)	30639 (4.55)	30856 (4.45)	32282 (4.55)	31259 (4.52)
Rental value of land	25729 (3.82)	41167 (5.93)	36021 (5.08)	34306 (4.96)
Depreciation cost	243569 (36.15)	243569 (35.11)	243569 (34.36)	243569 (35.19)
Total cost	673845 (100)	693659 (100)	708912 (100)	692139 (100)
Production (q)	963	990	1050	1001
Gross return	1011465	1039164	1102238	1050955
Net return	337620	345505	393325	358817
Cost of production (₹/ha)	1728	1731	1668	1709
Benefit-cost ratio	1.50	1.50	1.55	1.52

Note - figures in parentheses indicate their percentages of the total cost

-wheat cropping pattern (12). Within variable costs, seedling expenditure formed the largest component. In a one-hectare NVPH structure (10000 m²), around 29650 seedlings were planted at a time (15). Cucumbers of the Hiltan and Multistar varieties were cultivated. Seedling costs were considerably higher in polyhouses, with Sonepat showing the highest at ₹148529/ha, followed by Hisar (₹146789/ha) and Karnal (₹143594/ha). Harvesting typically began 45-50 days after planting, with 25-30 pickings per crop cycle. Harvesting costs were also the highest in Sonepat (₹60883/ha), followed by Karnal (₹55652/ha) and Hisar (₹53987/ha). The elevated cost in Sonepat may be due to a higher number of pickings and the employment of more skilled (and expensive) labour. The cost of fertilisers varied across districts, being highest in Karnal (₹30123/ha), followed by Sonepat (₹29197/ha) and Hisar (₹28412/ha). This increase was primarily due to the use of water-soluble fertilisers. Expenditure on pesticides was highest in Sonepat (₹16598/ha), followed by Hisar (₹16090/ha) and Karnal (₹15020/ha). Similarly, gap-filling costs were greatest in Sonepat (₹13662/ha), followed by Karnal (₹12365/ha) and Hisar (₹10445/ha). The higher costs in Sonepat were attributed to a greater mortality rate of seedlings and nematode infestation. The costs of hoeing, weeding and stacking were also highest in Sonepat (₹13131/ha), compared to Hisar (₹11747/ha) and Karnal (₹11397/ha). Stacking is a crucial cultural practice in cucumber cultivation under NVPH, as plants need to be tied with threads or other materials to prevent them from spreading

on the ground. Proper stacking helps in better crop management and higher productivity.

Returns

Table 1 presents the yields of cucumber cultivation under naturally ventilated polyhouses across different districts. The results indicate that Sonepat recorded the highest yield at 1050 quintals per hectare, exceeding Karnal (990 q/ha) and Hisar (963 q/ha) (6). In terms of total returns per hectare, Sonepat again led with ₹1102,238, followed by Hisar (₹1039,164) and Karnal (₹1011465). The highest net returns per hectare were also observed in Sonepat (₹393325), with Karnal and Hisar yielding ₹345505 and ₹337620, respectively. Correspondingly, the benefit-cost (B: C) ratio was highest in Sonepat at 1.55, surpassing the ratios of 1.50 observed in both Hisar and Karnal.

Cost and returns from cucumber cultivation under net houses

In this section, the results of a comparative economic analysis of cucumber cultivation under net houses in selected districts, with various costs and return components summarized, were presented in Table 2. The total cost of cucumber cultivation was highest in Karnal district, amounting to ₹558202 per hectare, followed by Sonepat (₹549087/ha) and Hisar (₹530380/ha). Among the components of total cost, variable costs accounted for the largest share, with Sonepat at ₹310274/ha, Karnal at ₹309973/ha and Hisar at ₹305793/ha. Land rental values were highest in Karnal

Table 2. Cost and returns of cucumber in net houses in Haryana (₹/ha)

Particulars	Hisar	Karnal	Sonepat	Haryana
Preparatory tillage	6390 (1.20)	5870 (1.05)	6885 (1.25)	6381 (1.17)
Ridging/ Bed preparation	6167 (1.16)	6450 (1.16)	6722 (1.22)	6446 (1.18)
Seedling cost	147171 (27.75)	148509 (26.60)	148024 (26.96)	147901 (27.09)
Gap filling	12456 (2.35)	12782 (2.29)	11803 (2.15)	12347 (2.26)
Total fertilizer cost	33913 (6.39)	37870 (6.78)	35068 (6.39)	35617 (6.52)
Hoeing, weeding and stacking	7451 (1.40)	8522 (1.53)	7957 (1.45)	7977 (1.46)
Cost of pesticide	13935 (2.63)	12937 (2.32)	13761 (2.51)	13544 (2.48)
Harvesting/picking	54217 (10.22)	52942 (9.48)	55125 (10.04)	54095 (9.91)
Irrigation	4089 (0.77)	3813 (0.68)	4631 (0.84)	4178 (0.77)
Variable cost	285788 (53.88)	289695 (51.90)	289975 (52.81)	288486 (52.85)
Interest on working capital (7 %)	20005 (3.77)	20279 (3.63)	20298 (3.70)	20194 (3.70)
Total variable cost	305793 (57.66)	309973 (55.53)	310274 (56.51)	308680 (56.55)
Management charges (10 %)	30579 (5.77)	30997 (5.55)	31027 (5.65)	30868 (5.65)
Risk Factor (10 %)	30579 (5.77)	30997 (5.55)	31027 (5.65)	30868 (5.65)
Rental value of land	25728 (4.85)	46313 (8.30)	36021 (6.56)	36020 (6.60)
Depreciation cost	106003 (19.99)	106003 (18.99)	106003 (19.31)	106003 (19.42)
Total cost	530380 (100)	558202 (100)	549087 (100)	545889 (100)
Production (q)	902	963	939	935
Gross return	947068	1011465	985530	981354
Net return	416688	453263	436443	435465
Cost of production (₹/ha)	1452	1431	1445	1443
Benefit-cost ratio	1.79	1.81	1.79	1.80

Note- figures in parentheses indicate their percentages of the total cost

(₹46313/ha), followed by Sonepat (₹36021/ha) and Hisar (₹25728/ha), mainly due to the prevailing rice-wheat cropping pattern in Karnal. Within variable costs, seedling expenditure was the largest component. In a one-hectare net house (10000 m²), approximately 28000-28500 seedlings were planted at a time. The Hiltan and Multistar cucumber varieties were cultivated. Seedling costs were highest in Karnal (₹148509/ha), followed by Sonepat (₹148024/ha) and Hisar (₹147171/ha). Harvesting in net houses typically begins 45-50 days after planting, with 25-30 pickings per crop cycle. The highest harvesting cost was recorded in Sonepat (₹55125/ha), followed by Hisar (₹54217/ha) and Karnal (₹52942/ha).

The higher harvesting cost in Sonepat was attributed to a greater number of pickings and the use of more expensive labour. Fertilizer costs under net house cultivation varied across districts, being highest in Karnal (₹37870/ha), followed by Sonepat (₹35068/ha) and Hisar (₹33913/ha). The elevated fertilizer cost was mainly due to the use of water-soluble fertilizers. Pesticide costs were highest in Hisar (₹13935/ha), followed by Sonepat (₹13761/ha) and Karnal (₹12937/ha), reflecting higher insect pest infestation in Hisar. Hoeing, weeding and stacking costs were also the highest in Karnal (₹8522/ha), followed by Sonepat (₹7957/ha) and Hisar (₹7451/ha). Stacking and manual weeding are important cultural practices in cucumber cultivation and the higher cost in Hisar was due to greater weed infestation (12).

Returns

Table 2 presents the returns from cucumber cultivation under net houses across different districts. The highest yield per hectare was recorded in Karnal (963 q/ha), followed by Sonepat (939 q/ha) and Hisar (902 q/ha). In terms of total production value, Karnal again led with ₹1011465/ha, followed by Sonepat (₹985530/ha) and Hisar (₹947068/ha). Net returns per hectare were highest in Karnal (₹453263), with Sonepat and Hisar following at ₹436443 and ₹416688, respectively. Interestingly, Sonepat exhibited the highest benefit-cost (B : C) ratio at 1.81, slightly surpassing the ratios of 1.79 observed in both Hisar and Karnal, indicating relatively better profitability in Sonepat despite lower yield and net returns.

Cost and returns from cucumber cultivation under walk-in-tunnels

This section presents the findings of a comparative economic study on cucumber cultivation under walk-in tunnels in selected districts. Table 3 summarizes variable costs, total costs and various components of returns. The highest total cost of cucumber cultivation was recorded in Sonepat (₹663585/ha), followed by Hisar (₹654662/ha). Among total expenditures, the largest share was attributed to variable costs, with Sonepat at ₹303187/ha and Hisar at ₹299697/ha. Land rental values were highest in Sonepat (₹36021/ha) compared to Hisar (₹25728/ha), primarily due to the extensive irrigation infrastructure in Sonepat and the neighboring National Capital Region (NCR). Within variable costs, seedling expenditure

Table 3. Cost and returns of cucumber in walk-in-tunnel in Hisar (₹/ha)

Particulars	Hisar	Sonepat	Haryana
Preparatory tillage	6340 (0.97)	6149 (0.93)	6244 (0.95)
Ridging/ Bed preparation	5547 (0.85)	6087 (0.92)	5817 (0.88)
Seedling cost	144907 (22.13)	148141 (22.32)	146524 (22.23)
Gap filling	11527 (1.76)	10451 (1.57)	10989 (1.67)
Total fertilizers cost	32151 (4.91)	30334 (4.57)	31242 (4.74)
Hoeing, weeding and stacking	10045 (1.53)	11168 (1.68)	10606 (1.61)
Cost of pesticide	14738 (2.25)	12921 (1.95)	13829 (2.10)
Harvesting/picking	50803 (7.76)	53496 (8.06)	52149 (7.91)
Irrigation	4034 (0.62)	4607 (0.69)	4321 (0.66)
Variable cost	280091 (42.78)	283352 (42.7)	281721 (42.74)
Interest on working capital (7 %)	19606 (2.99)	19835 (2.99)	19721 (2.99)
Total variable cost	299697 (45.78)	303187 (45.69)	301442 (45.73)
Management charges (10 %)	29970 (4.58)	30319 (4.57)	30144 (4.57)
Risk factor (10 %)	29970 (4.58)	30319 (4.57)	30144 (4.57)
Rental value of land	25728 (3.93)	36021 (5.43)	30874 (4.68)
Depreciation cost	238423 (36.42)	238423 (35.93)	238423 (36.17)
Total cost	654662 (100)	663585 (100)	659124 (100)
Production (q)	866	951	909
Gross return	909463	999042	954252
Net return	254801	335457	295129
Cost of production (₹/ha)	1867	1723	1795
Benefit-cost ratio	1.39	1.51	1.45

Note - figures in parentheses indicate their percentages of the total cost

was the largest component. In a one-hectare walk-in tunnel (10000 m²), approximately 24700 seedlings were planted at a time. The Hiltan and Multistar cucumber varieties were cultivated. Seedling costs were highest in Sonepat (₹148141/ha), followed by Hisar (₹144907/ha). Harvesting costs were also highest in Sonepat (₹53496/ha), compared to Hisar (₹50803/ha). The relatively higher harvesting cost in Hisar was due to a greater number of pickings per crop cycle. Fertilizer costs were highest in Hisar (₹32151/ha), followed by Sonepat (₹30034/ha), largely because of the use of water-soluble fertilizers. Pesticide costs were similarly highest in Hisar (₹14738/ha), with Sonepat following at ₹12921/ha.

Comparative cost and returns from cucumber cultivation under different structures in Haryana overall

This section presents the results of a comparative economic analysis of cucumber cultivation in Haryana under different protected structures. Table 4 summarizes variable costs, total costs and various components of returns.

The total cost of cultivation was highest in naturally ventilated polyhouses (NVPH) at ₹673845 per hectare, followed by walk-in tunnels (₹659124/ha) and net houses (₹545889/ha). Among the components of total cost, the largest share of variable costs was observed in net houses (₹308680/ha), followed by NVPH (₹306395/ha) and walk-in tunnels (₹301442/ha). The higher variable cost in net houses was primarily due to seedling, fertilizer and harvesting

expenses. Depreciation costs, representing the fixed component of expenditure, were highest in NVPH (₹243569/ha), followed by walk-in tunnels (₹238423/ha) and net houses (₹106003/ha).

Returns

Table 4 presents the returns from cucumber cultivation under different protected structures in Haryana. The results indicate that NVPH produced the highest yield at 963 quintals per hectare, followed by net houses (935 q/ha) and walk-in tunnels (909 q/ha). In terms of gross returns, NVPH again led with ₹1011465 per hectare, followed by net houses at ₹981354/ha and walk-in tunnels at ₹954252/ha (16).

Net returns were highest from the net house, ₹435465/ hectare, followed by NVPH and the walk-in-tunnel, at ₹337620 and ₹295129 per hectare, respectively. Benefit-cost ratio was found to be the highest in the net house, i.e., 1.80, compared to NVPH (1.50) and walk-in-tunnel (1.45), respectively.

Channel-wise description of each marketing channel on the basis of their share in the marketing of cucumber in selected districts

Channel-I: Producer → wholesaler-cum-commission agent → retailer → consumer

In the areas of Hisar, Karnal and Sonepat in Haryana, the cucumber marketing process in channel-I included the participation of two intermediaries, namely the wholesaler-cum-commission agent and

Table 4. Comparative cost and returns of cucumber in Haryana (₹/ha)

Particulars	NVPH	Net house	Walk-in-tunnel
Preparatory tillage	7234 (1.07)	6381 (1.17)	6244 (0.95)
Ridging/ bed preparation	7586 (1.13)	6446 (1.18)	5817 (0.88)
Seedling cost	146789 (21.78)	147901 (27.09)	146524 (22.23)
Gap filling	10445 (1.55)	12347 (2.26)	10989 (1.67)
Total fertilizer cost	28412 (4.22)	35617 (6.52)	31242 (4.74)
Hoeing, weeding and stacking	11397 (1.69)	7977 (1.46)	10606 (1.61)
Cost of pesticide	16090 (2.39)	13544 (2.48)	13829 (2.10)
Harvesting/picking	53987 (8.01)	54095 (9.91)	52149 (7.91)
Irrigation	4411 (0.65)	4178 (0.77)	4321 (0.66)
Variable cost	286350 (42.49)	288486 (52.85)	281721 (42.74)
Interest on working capital (7 %)	20045 (2.97)	20194 (3.70)	19721 (2.99)
Total variable cost	306395 (45.47)	308680 (56.55)	301442 (45.73)
Transport charge	36874 (5.47)	33451 (6.13)	28096 (4.26)
Management charges (10 %)	30639 (4.55)	30868 (5.65)	30144 (4.57)
Risk Factor (10 %)	30639 (4.55)	30868 (5.65)	30144 (4.57)
Rental value of land	25729 (3.82)	36020 (6.60)	30874 (4.68)
Depreciation cost	243569 (36.15)	106003 (19.42)	238423 (36.17)
Total cost	673845 (100)	545889 (100)	659124 (100)
Production (q)	963	935	909
Gross return	1011465	981354	954252
Net return	337620	435465	295129
Cost of production (₹/ha)	1728	1443	1795
Benefit-cost ratio	1.50	1.80	1.45

Note- figures in parentheses indicate their percentages of total cost the merchant, who facilitated the exchange between producers and ultimate buyers. Farmers engaged in the selling of produce to the wholesaler or commission agency (Table 5).

Table 4 showed that in the Hisar market, farmers got a net price of ₹923 per quintal, which represents 46.16 percent of the buyer price. Sonapat and Karnal markets followed, with net prices of 966 (44.94 %) and 845 (41.23 %), respectively. In the marketplaces of Karnal, Sonapat and Hisar, the seller paid ₹155, ₹154 and ₹127 per quintal, respectively, for the sale of the product. In the Sonapat, Hisar and Karnal marketplaces, the wholesaler-cum-commission agent's purchase price was respectively ₹1120, ₹1050 and ₹1000 per quintal. In the subsequent part of this route, the wholesaler-cum-commission agent sold the produce to the merchant, but in between, their costs were, respectively, ₹68, ₹53 and ₹39 per quintal in the Sonapat, Karnal and Hisar marketplaces. In Sonapat, Hisar and Karnal, the wholesaler-cum-commission agency selling price was ₹1450, ₹1300 and ₹1300 per quintal, respectively. In Sonapat, Karnal and Hisar, the net profit of the wholesaler-cum-commission agency was ₹262, ₹247 and ₹211 per quintal, respectively. In the Sonapat, Karnal and Hisar marketplaces, the merchant faced marketing expenses of ₹290, ₹258 and ₹249 per quintal, respectively. In Sonapat, Karnal and Hisar, the retail sale price or customer purchase price was ₹2150, ₹2050 and ₹2000 per quintal, respectively. In the marketplaces of Karnal, Hisar and Sonapat, respectively, the

merchant got net margins of ₹492, ₹451 and ₹410 per quintal, or about 24.00, 22.55 and 19.07 % of the buyer price (17).

Channel- II: Producer → supermarket → consumer

The marketing profits, price difference and expenses in the channel-II are displayed in Table 6. Supermarkets (such as Reliance fresh, Easy-Day, etc.) are engaged in this route between the supplier and the customer. In Hisar, Karnal and Sonapat, the producer's portion of the buyer price was 67.07, 61.48 and 60.90 %, respectively. In Karnal, Sonapat and Hisar, the supplier paid ₹155, ₹154 and ₹127 per quintal, respectively. The producer's selling price for the product in the Sonapat district market was ₹1250 per quintal and in the marketplaces of the Hisar and Karnal districts, it was ₹1200 per quintal. As a result, the producer's net price in Sonapat was ₹1096 per quintal, followed by ₹1073 in Hisar and ₹1045 in Karnal. The store paid ₹121 per quintal in Sonapat, ₹108 in Karnal and ₹96 in Hisar, correspondingly. Consumers paid ₹1800 per quintal in Sonapat compared to ₹1700 and ₹1600 per quintal in Karnal and Hisar.

Channel-III: Producer → consumer

In the selling of cucumbers, this is the quickest route. There were no middlemen between the provider and the customer in this route. The produce was distributed directly to customers by the supplier. According to the findings in Table 7, the seller in the Sonapat district

Table 5. Price spread of cucumber in channel-I (₹/ha)

Particulars	Hisar	Karnal	Sonepat	Haryana
Net price received by producer	923 (46.16)	845 (41.23)	966 (44.94)	911 (44.10)
Cost incurred by the producer	127 (6.34)	155 (7.55)	154 (7.15)	145 (7.03)
Packing material	10 (0.51)	10 (0.47)	11 (0.53)	10 (0.50)
Loading and unloading charges	6 (0.30)	8 (0.39)	8 (0.37)	7 (0.35)
Transportation	35 (1.77)	49 (2.39)	55 (2.56)	46 (2.24)
Post-harvest losses	75 (3.76)	88 (4.30)	79 (3.69)	81 (3.90)
Sub total	127 (6.34)	155 (7.55)	154 (7.15)	145 (7.03)
Sale price of producer/ purchase price of wholesaler	1050 (52.50)	1000 (48.78)	1120 (52.09)	1057 (51.13)
Loading and unloading charges	6 (0.30)	8 (0.39)	8 (0.37)	7 (0.35)
Post-harvest losses	33 (1.66)	45 (2.21)	60 (2.80)	46 (2.23)
Sub total	39 (1.96)	53 (2.60)	68 (3.17)	53 (2.58)
Net margin of wholesaler	211 (10.54)	247 (12.04)	262 (12.17)	240 (11.61)
Sale price of wholesaler/ purchase price of retailer	1300 (65.00)	1300 (63.41)	1450 (67.44)	1350 (65.32)
Cost incurred by retailer	249 (12.45)	258 (12.59)	290 (13.49)	266 (12.85)
Commission @ 8 %	104 (5.20)	104 (5.07)	116 (5.40)	108 (5.23)
Loading and unloading charges	6 (0.30)	8 (0.39)	8 (0.37)	7 (0.35)
Transportation	35 (1.75)	42 (2.05)	50 (2.33)	42 (2.05)
Post-harvest losses	104 (5.20)	104 (5.07)	116 (5.40)	108 (5.23)
Sub total	249 (12.45)	258 (12.59)	290 (13.49)	266 (12.85)
Net margin of the retailer	451 (22.55)	492 (24.00)	410 (19.07)	451 (21.82)
Sale price of retailer/ purchase price of consumer	2000 (100)	2050 (100)	2150 (100)	2067 (100)

Note - figures in parentheses indicate their percentages of the sale price of the retailer/purchase price of the consumer

Table 6. Price spread of cucumber in channel-II (₹/ha)

Particulars	Hisar	Karnal	Sonepat	Haryana
Net price received by producer	1073(67.07)	1045(61.48)	1096 (60.9)	1071 (63.02)
Cost incurred by the producer	127 (7.93)	155 (9.11)	154 (8.54)	145 (8.55)
Packing material	10(0.64)	10 (0.56)	11 (0.64)	10 (0.61)
Loading and unloading charges	6 (0.38)	8 (0.47)	8 (0.44)	7 (0.43)
Transportation	35 (2.21)	49 (2.88)	55 (3.06)	46 (2.73)
Post-harvest losses	75 (4.70)	88 (5.19)	79 (4.41)	81 (4.75)
Sub total	127 (7.93)	155 (9.11)	154 (8.54)	145 (8.55)
Sale price of producer/ purchase price of supermarket	1200 (75.00)	1200 (70.59)	1250 (69.44)	1217 (71.57)
Cost incurred by the supermarket	96 (6.00)	108 (6.37)	121 (6.72)	108 (6.37)
Loading and unloading charges	6(0.38)	6 (0.35)	6 (0.33)	6 (0.35)
Post-harvest losses	90 (5.63)	102 (6.01)	115 (6.39)	102 (6.02)
Sub total	96 (6.00)	108 (6.37)	121 (6.72)	108 (6.37)
Net margin of the supermarket	304 (19.00)	392 (23.04)	429 (23.83)	375 (22.06)
Sale price of supermarket / purchase price of consumer	1600 (100)	1700 (100)	1800 (100)	1700 (100)

Note- figures in parentheses indicate their percentages of the sale price of the retailer/purchase price of the consumer

markets got a net price per quintal of ₹1346, or 89.75 % of the buyer price. Hisar and Karnal markets received net prices per quintal of ₹1173 (90.24 %) and ₹1145 (88.09 %), respectively. The producer's selling expenses were ₹155 per quintal in Karnal and ₹154 and ₹127 per quintal in Sonepat and Hisar, respectively. The Sonepat region had the highest sale price of the product at ₹1500 per quintal, followed by Hisar and Karnal at ₹1300 each. Researchers found that direct marketing was where manufacturers made the most money from consumers (18, 19).

Marketing efficiency

It is clear from Table 8 that the marketing effectiveness of cucumber in various marketplaces and marketing platforms within the chosen Haryana regions. In Hisar, Sonepat and Karnal marketplaces under

channel-I, marketing effectiveness according to Acharya's approach was determined to be 1.06, 0.91 and 0.87 %, respectively. Marketing effectiveness in Hisar, Karnal and Sonepat was determined to be 2.04, 1.60 and 1.56 %, respectively, on channel II. Marketing effectiveness for channel III was determined to be 9.25, 8.76 and 7.40 % in Hisar, Sonepat and Karnal, respectively. Channel III was the most effective marketing channel among the three in the various marketplaces of the chosen regions, according to this effectiveness indicator. This was a result of the absence of intermediates in channel III. Additionally, as the number of market middlemen between the supplier and the customer dropped, marketing effectiveness increased. According to early studies, the producer-to-consumer route was the most effective of all currently used marketing channels (18, 19).

Table 7. Price spread of cucumber in channel-III (₹/ha)

Particulars	Hisar	Karnal	Sonepat	Haryana
Net price received by producer	1173 (90.24)	1145 (88.09)	1346 (89.75)	1221 (89.37)
Cost incurred by producer	127 (9.76)	155 (11.91)	154 (10.25)	145 (10.63)
Packing material	10 (0.79)	10 (0.74)	11 (0.76)	10 (0.76)
Loading and unloading charges	6 (0.46)	8 (0.62)	8 (0.53)	7 (0.54)
Transportation	35 (2.72)	49 (3.77)	55 (3.67)	46 (3.39)
Post-harvest losses	75 (5.79)	88 (6.79)	79 (5.29)	81 (5.9)
Sub total	127 (9.76)	155 (11.91)	154 (10.25)	145 (10.63)
Sale price of producer/ purchase price of consumer	1300 (100)	1300 (100)	1500 (100)	1367 (100)

Note - figures in parentheses indicate their percentages of the sale price of the retailer/purchase price of the consumer

Table 8. Market efficiency of cucumber in different marketing channels (₹/ha)

Channel	Market	1	2	3	4	5	6	7	8
		CPC	TMC	TNM	NPRF	VA (1-4)	CM	SM	AM
I	Hisar	2000	415	460	923	1077	2.60	4.82	1.06
	Karnal	2050	466	505	845	1205	2.59	4.40	1.06
	Sonepat	2150	512	552	966	1184	2.31	4.20	1.06
	Haryana	2067	464	506	911	1155	2.49	4.45	0.87
II	Hisar	1600	223	304	1073	527	2.36	7.17	1.00
	Karnal	1700	263	392	1045	655	2.49	6.46	0.91
	Sonepat	1800	275	429	1096	704	2.56	6.55	2.04
	Haryana	1700	254	375	1071	629	2.48	6.70	1.60
III	Hisar	1300	127	0	1173	127	1.00	10.24	1.52
	Karnal	1300	155	0	1145	155	1.00	8.39	1.56
	Sonepat	1500	154	0	1346	154	1.00	9.74	9.25
	Haryana	1367	145	0	1221	145	1.00	9.40	7.40

CPC: Consumer purchase price, TMC: Total marketing cost, TNM: Total net margin, NPRF: the net price received by farmers, VA: Value added, CM: Conventional method, SM: Shepherd's method and AM: Acharya's method.

Conclusion

The present study provides a comprehensive economic analysis of cucumber cultivation under different protected structures in Haryana. Among the structures, NVPH incurred the highest total cost of cultivation at ₹673845/ha, followed by walk-in tunnels (₹659124/ha) and net houses (₹545889/ha). Variable costs constituted a major portion of total expenditure, with net houses recording the highest at ₹308680/ha, primarily due to seedling, fertilizer and harvesting costs. Depreciation, a fixed cost component, was highest in NVPH (₹243569/ha), reflecting the greater capital investment required. Yields and returns varied across structures and districts. NVPH achieved the highest average yield of 963 q/ha, followed by net houses (935 q/ha) and walk-in tunnels (909 q/ha). While NVPH provided the highest gross return of ₹1011465/ha, net returns were maximized under net houses (₹435465/ha) owing to lower total costs, resulting in the highest benefit-cost ratio of 1.80, compared to 1.50 in NVPH and 1.45 in walk-in tunnels. District-wise, Sonepat led in NVPH yield (1050 q/ha) and net returns (₹393325/ha), while Karnal reported the highest net returns under net houses (₹45263/ha). Marketing analysis revealed that channel III was the most efficient, with producers receiving 88-90 % of the consumer price and achieving the highest marketing efficiency (7.40-9.25 %) across all districts. Overall, cucumber cultivation under protected structures is economically viable, with net houses offering superior profitability and direct marketing providing the highest returns to producers. Strategic selection of structure type and marketing channel can significantly enhance income for cucumber growers in Haryana, promoting sustainable horticultural practices and optimal resource utilization.

Authors' contributions

PKN prepared the design of the work, acquisition of data, data analysis and interpretation. PS drafting of manuscript. AK critically revised the article. SS¹ drafting of references and SS² drafting of manuscript. All authors read and approved the final manuscript. SS¹-Sharad Sachan, SS²-Shivalika Sood

Compliance with ethical standards

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