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Relevance of modern technology in protected cultivation of vegetables in India

A comparison between low-tech, mid-tech and hi-tech technology in the state of Maharashtra

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Summary

In order to enhance the acceptance of new technologies by the farmers, there is a need for standard technics of different types of protected cultivation. This study aims to develop a comparison of a low-tech, mid-tech and high-tech structure to build a complete standard for Indian farmers. The objective is to determine which model would be the most suitable for Indian farmers in the State of Maharashtra by calculating their economic feasibility, their efficiency of production and by studying the scope of implementing modern technology according to the farmers perception.
The main results are that subsidies from the government must be integrated to the calculations in order to generate a positive annual income. In case of 50% subsidies, the Mid-tech model obtains the best profitability and economic feasibility. The high-tech model shows the best efficiency of production due to the soilless cultivation which enables to reduce the workforce required and the inputs.
The study reveals many available opportunities to enhance the adoption of technology by Indian farmers, who have a high willingness to implement modern technology in their cultivation system. The main constraint highlighted is the lack of knowledge and know-how required to adopt modern technologies and the initial cost of investment. Thus, the Mid-tech model which also includes modern technology at a more affordable cost than the high-tech model would be the most suitable model for Indian farmers in Maharashtra. Moreover, there is a need from private and public institutes to develop the trainings activities for improving the skills and knowledge required at farmers level. The Mid-tech model developed in this study should be implemented to realize calculations in real conditions and, according to the results, it should be implemented at farms level by Indian farmers.

Key words: *modern technology, protected cultivation, Maharashtra, vegetables*

Preface

A collaboration between an international Dutch company (HollandDoor) and KVK Baramati has been settled to create an Indo-Dutch project: Centre of Excellence for vegetables (CoE). In the area of this collaboration, many projects are emerging. One of them being the implementation of a Hybrid model of greenhouse more adapted to the Indian farmers investment capacity. This thesis aims to provide a reliable comparison between the current models of protected cultivation, which will help the implementation of the new Hybrid model. Therefore, this thesis is part of the collaboration between Hollandoor and Centre of Excellence, Baramati, and aims to analyze the scope for implementing high-tech technology into Indian companies.

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Chapter 1: Introduction

India is the second largest producer of vegetable crops in the world with 8.6% of the world production (FAO 2020). However, according to Sanwal, Sk. *et a*l (2004), its vegetable production is below the requirements if the balanced diet is provided to every individual. The present production of 169.1 million tons of vegetables (APEDA, 2015) should reach 250 million tons by 2024- 2025 (Singh, 1998). There are different opportunities to achieve this target, as expanding the area of cultivation for vegetable crops, using hybrid seeds, or improving agro-techniques. Another potential approach is to improve and promote the production of vegetables under protected cultivation (Singh, 1998; Singh *et al*., 1999).

The use of protected cultivation technologies for commercial production of vegetables is growing rapidly as compared to open land cultivation. In open land cultivation climate, crop diseases, insects and virus are the main factors impacting the productivity. But in controllable condition the climate and diseases do less affect the production level, which increases the productivity and ensure a better quantity and quantity (Suryawanshi, 2016, Nimbrayan *et al*, 2018; Wani *et al*, 2011).
Thus, the cultivation of vegetables under polyhouse can be a solution to overcome biotic and abiotic stresses.
It also enables a production round the year of high value vegetables, like capsicum, cucumbers ant tomatoes, especially, during off-season.
The greenhouse technology can be a key for sustainable crop production as it holds an extreme potential for increasing the productivity and reducing the inputs as fertilizers, water and pesticides.

On one hand, technology for production of high-value horticulture crops in protected conditions is being transferred to the producers effectively by horticulture extension system. On the other hand, Indian industries have developed indigenous technology and build-up capacity to design and fabricate infrastructure for protected cultivation in varying agroclimatic conditions in the country (Bijay, 2017). However, the high initial cost is one of the greatest worries in the adoption of the technology by the farmers (Murthy, 2009; Jadhav and Rosentrater 2017).

There are many different types of polyhouses used in India, as tunnel type (cold climate greenhouse), Quonset (semi-circular/ subtropical greenhouse), gable type (shopping roof), ridges and furrows greenhouses, ground to ground greenhouses, etc.
As mentioned by Murphy (2009), the cost of the polyhouse structure is a decisive factor for its adoption by farmers and sustainability of vegetable production. It mainly depends on the quality of materials used for the structure and the equipments.

In order to enhance the acceptance of new technologies by the farmers, there is a need for standard technics of different types (low-tech, mid-tech and high-tech) of protected cultivation. Moreover, the development of business models appears to be necessary for the costs estimation of implementing new technologies into protected cultivation system. Indeed, as mentioned by Foster and Rosenzweig (2010, cited by Rehman and Hussain, 2016), the main drivers of successful agricultural technologies are the availability and affordability of technology, and the farmers expectation that their adoption will remain profitable.
Then, a comparison between the different systems including different aspects of sustainability as economics, social and environmental impacts would be an added value in the decision process of implementing a type of structure.

The aim of this thesis is to **demonstrate that adapting the modern technology developed in this comparison can improve the long-term benefits for Indian farmers while reducing the use of inputs, limiting the workforce required and increasing the productivity and quality.**

Three models of protected cultivation have been developed:

- A low-tech structure which represent the Indian current protected cultivation structure with naturally ventilated polyhouse,
- A high-tech structure which represent air-forced ventilated polyhouse as developed for the Indo-Dutch project into the Centre of Excellence for vegetables, KVK Baramati (Maharashtra, district Pune).
- A new model, called Hybrid polyhouse, developed as Mid-Tech technology. This model consists of a mix between low tech and high-tech presented previously.

The technology of each structure has been highlighted as for its impact on the financial management and efficiency of the production.

This study aims to develop a comparison of each structure to build a complete standard for Indian farmers. For this purpose, the main question answered during this research is the following: **which model of protected cultivation between Low-tech, Mid-Tech and High-tech would be the most suitable for Indian farmers in the State of Maharashtra?**

This question has been divided into few sub-questions:

- ➔ What are the investment costs, running costs and net return expected for each kind of structure (naturally ventilated polyhouse, air-forced ventilation polyhouse and Hybrid model)?
- ➔ For each system, what is the efficiency of production in terms of labour force (in terms of number of workers required for one crop cultivation and total cost of labour) and the quantity of water, fertilizers and chemicals used?
- ➔ What is the perception of technology by Indian farmers and how willing are they to implement it in their production system?

The thesis is organized in three parts. In the first part, the three structures presented earlier have been compared to each other on the production efficiency (running costs vs benefits), productivity (amount of production per season for a determined work force) and return on investment. In order to base the study on existing data, the economic calculations are based on tomatoes production under protected cultivation in the State of Maharashtra.

In the second part, the social and environmental impacts have been assessed through the labor characteristics (number of workers required for one crop cultivation and total cost) and the efficiency of inputs (amount of water, pesticides and fertilizers used and percentage of losses for these items). Conclusions have been drawn from these comparisons, in order to establish clearly the impacts of each structure and the relevance of high technology in protected cultivation for vegetables in Indian context.

In a third part, the willingness of farmers to implement technology into their production system have been studied and conclusions have been drawn on the relevance of modern technology structure and equipments as a sustainable model of production for Indian farmers. These conclusions can serve as a guidance in the decision-making process of farmers to implement a protected cultivation system in their company.

Chapter 2: Material and methods

1. Technical standards of the three models and general specifications

This part aims to describe the characteristics of three models of protected cultivation, respectively naturally ventilated polyhouse (low-tech structure), air-forced ventilation polyhouse (high-tech structure) and Hybrid model (mid-tech structure).

1.1.Naturally Ventilated Polyhouse: Low-Tech model

The Naturally Ventilated Polyhouse (Figure 1) is the most represented structure in Maharashtra (NHB, 2019). It is constructed with local materials and does not use any specific control devices to control the climatic conditions inside the polyhouse.

The model used for the comparison is based on the design and characteristics developed by Kumar (2016) and Yadav (2018). The main equipments used are shading materials like nets to reduce the light intensity, ultraviolet (UV) film as cladding materials and openings of side walls to reduce the temperature. Openings are also present on the roof to increase the ventilation capacity, protected by insect-nets.
All operations in these structures are manually operated.

Woods, bamboo, GI pipe (Tubular), angle iron and aluminum are common materials used for the framework of a polyhouse (Yadav, 2018). For the comparison, the design of galvanized tubular structure has been chosen as the life of these structures are longer than the with woods or bamboo (Kumar, 2016).
The main components of the Naturally Ventilated Polyhouse included in the comparison are presented in Table 1.

Galvanized Tubular structure 2mm thickness
Column 60mm OD
Foundation 42mm OB/48mm OD
Arches 42mm OD
Purlins 44mm OD
Clamps, Nut bolts, Fitting and accessories
Entry room with double door
UV stabilized insect net for roof and side covering buried in ground
Alluminium locking profile with zig zag spring for fixing of shade net for roof
Appron (1m) HDPE Woven Fabric (150-200 GSM)
UV stabilized shade net 50% with nylon support cables, pulleys, side support with clamps with manual collapsible arrangement

Table 1: Components of Naturally Ventilated Polyhouse. *Source: Centre of Excellence, KVK Baramati*

Figure 1&2: Naturally Ventilated Polyhouse *Credit: C. Durot*

1.2.Air-Forced Ventilation Polyhouse: High-Tech model

The Air-Forced Ventilation Polyhouse (Figure 2) is considered in this study as a High-Tech model of cultivation. The environment parameters as temperature, humidity, irrigation and fertigation are fully controlled. The Polyhouse is fully in automatized by a computer. As described by Sonawane (2016), the automation system refers to a network of sensors and controllers, which detects the environmental changes of the Polyhouse and take necessary action to match the predefined set of normal values. This model of cultivation can be used to produce high value vegetables for both local consumption and long-distance supply (Yadav, 2018). For this model, the production is realized in soil-less cultivation to have an accurate control of all inputs (irrigation, fertigation and chemicals). The irrigation and fertigation are operated with a drip system, and a thermal screen is protecting the crops from the sun radiations.

Figure 3&4: Air-Forced Ventilation Polyhouse *Credit: C. Durot*

In the study, this model is based on the structure developed in the Centre of Excellence, KVK Baramati as an Indo-Dutch project. It includes the structural equipments of the polyhouse and the diverse technological equipments used to control the abiotic parameters. The items are listed in Table 2.

Polyhouse structure	Polyhouse equipments
Anchorage	Silo's
Posts	Drip and drain irrigation
Monobloc forget connecting post head	Fans
Patented ISOCLAIR gutters	Electrical installation
Arch	Climate computer & Irrigation Unit & Disinfection unit
Fronts	Engineering
Plastic clamping, clips, Suspension for crops	Civil materials
Access	Pumps
Roof	Humidity control (gutters / fogging system)
Frontals & Laterals	Rows
Double ridge vent and side-curtain vent	Growing bags
Insect-proof net	A&B tanks
Thermal screen	

Table 2: Components of Air-Forced Ventilation Polyhouse. *Source: Centre of Excellence, KVK Baramati*

1.3.Hybrid model: Mid-Tech Polyhouse

The Hybrid model (Figure 3) is a new structure in development. It is considered as mid-tech technology, as the level of technology is between the Naturally Ventilated Polyhouse and the Air-Forced Ventilation Polyhouse. The criteria and equipments have to be defined along the study, as the role of this structure is to increase the productivity compared to the current Indian model with the help of technological equipments, but to have a lower cost than the High-Tech model in order to limit the financial constraints of adoption by Indian farmers. The main characteristics of this structure (see Table 3) are the following: the production is made in soil-less cultivation with drip lines and a A&B tanks for fertigation. Butterflies are used on the top of the structure to increase the ventilation, and the sides can be open manually. A high-pressure fog system is also used to enable a certain humidity control, especially in the context of water scarcity. The water used for irrigation is not collected, as this investment would be too expensive for this model.

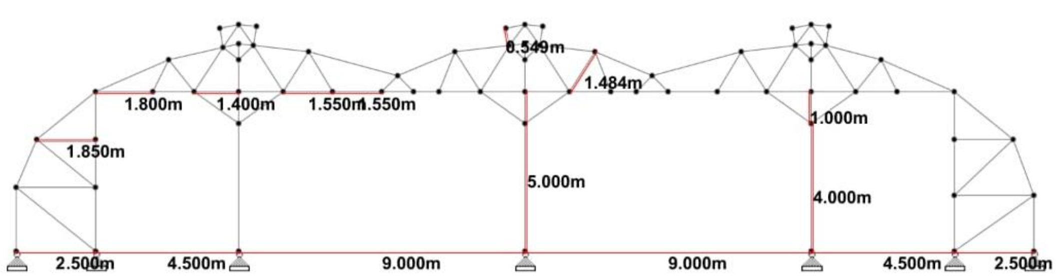

Figure 5: Scheme of Hybrid model *Source:* HollandDoor

The framework of the Hybrid model is realized on the same model as the Naturally Ventilated Polyhouse, with a galvanized tubular structure, a shade net included on the top and UV stabilized transparent low-density polyethylene. This cladding, used in the three types of polyhouse, creates greenhouse effects and participate in making a favorable microclimate favorable for plant growth and development (Yadav, 2018). To make the structure cost effective, the material for the frame needs to be selected cheaper, locally available and easy to use for fabrication, but should be strong enough to withstand against normally occurring high wind pressure and corrosion or weathering in soil and climatic moisture (P R Bhatnagar, 2014).

Polyhouse structure	**Polyhouse equipments**
Galvanized Tubular structure 2mm thickness	Silo's
Column 60mm OD	Shade net
Foundation 42mm OB/48mm OD	Fogging system (humidity control)
Arches 42mm OD	Drip lines system
Purlins 44mm OD	Buterflies on the top
Clamps, Nut bolts, Fitting and accessories	A&B fertigation tank with dosing pump
Entry room with double door	Insect net
UV stabilized insect net for roof and side covering buried in ground	
Aluminum locking profile with zig zag spring for fixing of shade net for roof	
Appron (1m) HDPE Woven Fabric (150-200 GSM)	
UV stabilized shade net 50% with nylon support cables, pulleys, side support with clamps with manual collapsible arrangement	

Table 3: Components of Hybrid model of Polyhouse. *Source:* HollandDoor

2. Economical aspects of each model

2.1. Investment costs

The investment cost of each structure, materials and technologic equipments have been described as the depreciation cost according to the shelf-life. Moreover, the maintenance costs have been estimated in order to determinate the annual cost per m² of each model.

2.2. Running costs

The costs of production have been determined in each model, based on the production of tomatoes. The costs are defined for a full cultivation from the transplantation of seedlings to the harvest. The packaging, transporting and marketing costs are not included. Moreover, as the Hybrid model is not yet implemented in India, the costs are based on estimations.

2.3. Productivity and benefits

This part will contain the average yield obtained by the farmers per m² for each model. As for the previous parts, the data about Hybrid model are also based on estimations. The expected benefits have been calculated for each model, as for the gross and net income. Because of the strong fluctuation of prices during the year in India and between the different markets, a fixed price per Kg have been defined to facilitate the calculations. For each model, the BCR (Benefits / Costs Ratio) has been calculated.

2.4. Return on investment

The return on Investment have been calculated for each model as for the Pay-Back period. The objective is to give a clear idea of the expected costs and benefits, and to give farmers an economic standard model of each structure. This overview should be an added value in the process of decision making for implementing a protected cultivation structure into their production system.

3. Efficiency of production

3.1. Workforce

For the three models of protected cultivation, the total number of workers has been determined. Based on the average Indian salary, the total cost of workforce has also been defined.

3.2. Amount of water, fertilizers and pesticides used

As the environmental footprint is becoming a major concern in agriculture, three points have been measured to assess the impact of each structure. The amount of water and fertilizers used for a complete cultivation of tomatoes have been determined. The number of treatments (sum of chemical and biochemical) against pests and diseases have also been calculated in order to highlight differences between each model of protected cultivation.

3.3. Losses of water, fertilizers and pesticides due to the equipments

As the management of his inputs is highly related to the farmer's knowledge, influences and external pressures, only the factors directly depending upon the structure have been assessed. The percentage of losses has been estimated for each model. These losses are limited to the water, the fertilizers and the sprays of chemicals. The losses are estimated based on the statement that they are due to the efficiency of technologic equipments (ex: drip system) and climate (depending on structural equipments as hermetical structure or ventilation system etc.).

4. Perception of technology by Indian farmers

4.1. Position toward modern technology

In order to show the relevance of implementing modern technology in Indian protected cultivation for vegetables, it is important to assess the perception of farmers toward this technology. This perception has been assessed by asking directly the farmers their general opinion about modern farming technology and their willingness (yes or no question) to implement it in their own system of cultivation.

4.2. Constraints and opportunities in adoption of technology

This part aims to define the main constraints of adopting technology into the cultivation system for Indian farmers. The objective is to highlight the main challenges and benefits they are perceiving and is mostly based on literature research and questions to farmers.

5. Collection of data

5.1. Primary data

The primary data for this study have been collected through three different ways:

- Questionnaire to Indian farmers from Maharashtra (Annex 1)

  In order to favorize a high number of answers, the form has been submitted to the farmers during the training sessions both in KVK, Baramati and Centre of Excellence for vegetables, Baramati. The audience of these trainings are mostly vegetables and cereals producers, and educated people (importance of sustainable farming awareness, reading and writing skilled). The questionnaire is written both in English and Marathi, and the interpretation has been done with the help of a translator for open questions for the case of answer written in Marathi. The questionnaire has also been submitted to the farmers during consultancy visits by advisors in order to target also farmers less involved in training sessions.
- Interviews of companies and organisms

  Divers companies and organisms have been consulted and/or interviewed in order to collect information on protected cultivation systems. The main questions developed during these interviews are related to the technical aspects of each model, farmer's technical practices, operating and relevance of technologic equipments integrated to each structure and the opportunities and constraints of technology for Indian farmers.

5.2. Secondary data

The secondary data required to realize this study have been collected from different sources as governmental documents, the National Horticulture Board, scientific studies report, advising and consultant organizations and training centers.

The economic data have been collected through divers' organisms and companies as polyhouses/greenhouses manufacturers, training centers and demonstration organisms. These data are based on the example of tomatoes production. As tomatoes are considered as cash crop in Indian context, various studies have been conducted on their production. Economic data are more available for this example both for current Indian polyhouse and air-forced ventilation polyhouse. The economic data have been collected in a table for each model of protected cultivation.

Chapter 3: Results

1. Collection of primary data

➢ Economic analysis and efficiency of production

The costs of investment, maintenance, production and the charges of depreciation for High-tech and Low-Tech polyhouses are based on the data from the Centre of Excellence for vegetables, KVK Baramati (Maharashtra, District. Pune). The high-tech model, Air-Forced Ventilated Polyhouse implemented in the Centre for production and demonstration purpose has a total working size of 5,760.00m² and is divided in 4 compartments in soilless cultivation, each of them having a production of different crop. For the cost analysis, only one compartment has been studied were a production of tomatoes is conducted. The Low-tech model which represent the Indian type of polyhouse, called Naturally Ventilated Polyhouse has a working size of 1,008.00m² in soil cultivation for tomatoes. The data used for the Mid-tech polyhouse, called Hybrid model have been estimated as this model is not implemented yet.

➢ Interviews and questionnaires to farmers

The main interview conducted during this study was from Mr. Sunil Rewar, National Horticultural Board in Maharashtra (Annex 4).
A total number of 62 respondents have been collected through the spread of questionnaires to farmers. Sixteen districts are represented on the 36 existing districts in Maharashtra. The questionnaires have been collected during training sessions and farm visits in different districts. For the farmers mentioning their qualifications, the level of education is situated at 7th degree (1 person), 10th degree (1 person), 12th degree (4 people), Bachelor (15 people), Master (10 people) and PhD (1 person). The age of respondents is shown in figure 6 per category.

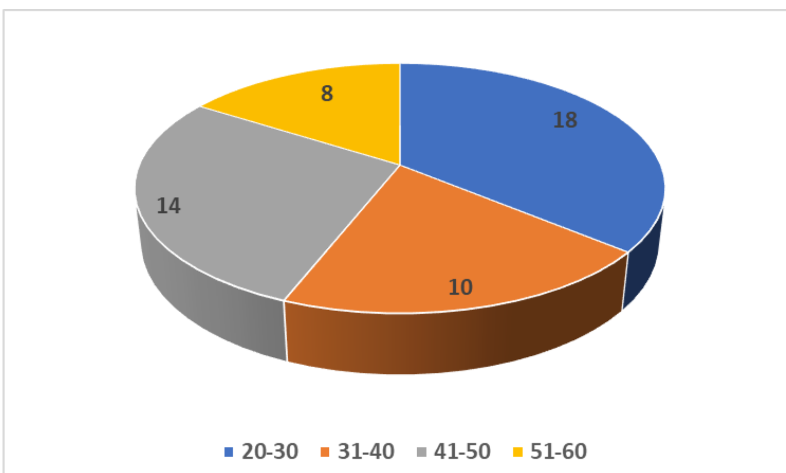

Figure 6: Age of respondents per category

A total of 50 respondents indicated their age. The most represented categories are between 20-30 and 41-50 years old. Around 80% of the respondents between 20 and 30 years old were questioned during training sessions whereas 55% of respondents between 41 and 50 years old were questioned during fields visits.

2. Economical aspects: costs vs productivity

2.1. Investment costs

In this part, the detailed initial cost of investment is described for the three models in Indian rupees.
Some equipments included in the structure are bought from European companies for which the cost is in euros. In order to have a final investment cost in Indian rupees, the currency has been fixed at CIR. 1-/ euro = INR. 78-/ rupees. The depreciation and the maintenance costs are also mentioned as structural and equipments charges. These charges are presented in annual cost only for the investment, and do not include the running costs which will be detailed in the next part. Also, the filtration system for water and the water storage are not included into the structural and equipment items. Indeed, it is assumed that these items are already present since the quality of water must be assured in all kind of irrigation purpose.

For the Hybrid model and the Naturally Ventilated polyhouse, it is assumed that each investment cost is amortized on the polyhouse surface only (respectively 1,000.00m² and 1,008.00m²). However, the cost of investment presented for the Air-Forced Ventilated Polyhouse are based on a study case of a high-tech polyhouse with a total area of 5,760.00m² divided in four compartments of 1,440.00m² each. The calculations are based on only one compartment; thus, each cost is reported for this compartment.

Table 4: Investment costs of structure for
Naturally Ventilated Polyhouse, Air-Forced Ventilation Polyhouse and Hybrid model

	Air Forced Ventilated Polyhouse (1440m²)		Naturally Ventilated Polyhouse (1008m²)		Hybrid model (1000m²)	
	Total cost	Cost per m²	Total cost	Cost per m²	Total cost	Cost per m²
Structure	4,831,682.07	3,355.33	164,335.33	163.03	306,119.32	160.60
Butterflies (x6)	959,150.00	666.08				
Roof / Polyethylene	205,122.00	142.45				
Double ridge vent	324,195.00	225.14				
Sides curtain vent			17,021.16	16.89	16,886.07	16.89
UV Stabilized Insect-proof net	125,474.00	87.13	87,232.00	86.54	86,539.68	86.54
UV stabilized shade net 50%	584,395.00	405.83	39,979.78	39.66	39,662.48	39.66
Other expenses (construction, installation, transport, duty, VAT)	624,147.73	433.44	245,845.51	243.89	245,845.51	243.89
Total cost	7,654,165.79	5,315.39	554,413.78	550.01	695,053.06	547.58

The Hybrid model's structure is built on the same model as the Naturally Ventilated Polyhouse. Thus, the costs remain the same between the two models. The structure includes also the butterflies and the polyethylene used for the roof as they are included in the total structural cost supplied by the local companies. The costs are based on the local market price except for the Air-Forced Ventilated polyhouse for which most of the investment were coming from the European market. In consequence, the transportation costs and import duties are higher with respectively 433.44 rupees per square meter for the high-tech model and 243.89 rupees per square meter for the low-tech and mid-tech (hybrid) models.

Table 5: Investment costs of equipments for
Naturally Ventilated Polyhouse, Air-Forced Ventilation Polyhouse and Hybrid model

	Air Forced Ventilated Polyhouse (1,440.0m²)		**Naturally Ventilated Polyhouse (1,008.0m²)**		**Hybrid model (1,000.0m²)**	
	Total cost	Cost per m²	Total cost	Cost per m²	Total cost	Cost per m²
Drip and drain irrigation	136,800.00	95.00			95,000.00	95.00
Drip irrigation online			73,080.00	72.50		
Polyethylene tank (A&B) 500L capacity	6,000.00	4.17			6,000.00	6.00
Fertilization tanks (x5)			10,000.00	9.92		
Fans (x4)	33,000.00	22.92				
Air circulation fans x5					41,250.00	41.25
Electrical installation	21,600.00	15.00			15,000.00	15.00
Hortimax CX500 Climate computer + Irrigation unit	682,500.00	473.96				
Climate control : Fertimix Go					1,178,700.00	1,178.70
Vibrator	5,000.00	3.47				
Fertimix CX600 Mixing tank	682,500.00	473.96				
Humidity control (gutters / fogging system)	115,200.00	80.00	80,640.00	80.00	80,000.00	80.00
Rows	48,000.00	33.33			32,000.00	32.00
Total cost	1,730,600.00	1,201.81	163,720.00	162.42	1,447,950.00	1,447.95

As shown in table 5, the investment costs for the equipments in each model are highly fluctuating. In the Naturally Ventilated Polyhouse, the cultivation system is conducted in soil whereas the cultivation is conducted in soilless for the Air Forced Ventilated Polyhouse and the Hybrid model. No automation is used for the Naturally Ventilated Polyhouse except a fogging system to control the humidity in the polyhouse. The cost of pump for water is not included as it is assumed the farm already owns one for farming purpose.

Table 6: Annual charges for depreciation and maintenance

Annual costs (Indian rupees)	**Air Forced Ventilated Polyhouse**	**Naturally Ventilated Polyhouse**	**Hybrid model**
Depreciation per m²	92.30	27.15	92.01
Maintenance per m²	59.25	5.39	16.48

The depreciation charges shown in table 6 are based on the Dutch calculation for which a 15 years lifespan is equivalent to 7% yearly depreciation. The maintenance costs are estimated with a percentage. All electrical installations (e.g. climate control unit, Fertimix Go…) are estimated at a 0.5% maintenance, while the polyethylene sheets, insect nets, thermal nets, drip irrigation and fogging systems are esteemed to have a higher deterioration rate thus the percentage of maintenance is fluctuating from 1 to 2.5%.

2.2. Running costs

Table 7: Running costs of tomatoes in each structure

Structure	Air Forced Ventilated Polyhouse (1,440.0m²)		Naturally Ventilated Polyhouse (1 acre)		Hybrid model (1,000.0m²)	
	Total cost	**Cost/m²**	**Total cost**	**Cost/m²**	**Total cost**	**Cost/m²**
Soil preparation			8,800.0	2.20		
Red soil			84,650.0	21.16		
Plastic mulch cover			14,000.0	3.50		
Soil fumigation			64,400.0	16.10		
Grow bag	5,200.0	3.61			3,608.0	3.61
Rope	3,000.0	2.08	9,870.0	2.47	2,400.0	2.40
Tomato hook	6,000.0	4.17	20,000.0	5.00	4,163.0	4.16
Media cocopeat	24,000.0	16.67			16,800.0	16.80
Sterilization of media	3,000.0	2.08			2,100.0	2.10
Seedlings	32,000.0	22.22	100,000.0	25.00	22,200.0	22.20
Fertilizers	55,858.0	38.79	153,800.0	38.45	38,790.0	38.79
Crop protection / pesticide	7,517.0	5.22	82,800.0	20.70	5,220.0	5.22
IPM Sticky traps	900.0	0.63	1,500.0	0.38	630.0	0.63
Electricity	15,000.0	10.42	1,000.0	0.25	5,325.0	5.33
Management charges	10,080.0	7.00	40,000.0	10.00	9,000.0	9.00
Leaf analysis	2,500.0	1.74				
Advisory services			8,000.0	2.00		
Total labor cost	60,593.0	42.08	214,400.0	53.60	44,700.0	44.70
Total variable cost	**225,647.0**	**156.70**	**803,220.0**	**200.81**	**154,935.0**	**154.94**
Rental value of land	10,800.0	7.50	30,000.0	7.50	7,500.0	7.50
Total fixed cost	**10,800.0**	**7.50**	**30,000.0**	**7.50**	**7,500.0**	**7.50**
Total running costs	**236,447.0**	**164.20**	**833,220.0**	**208.31**	**162,435.0**	**162.44**

The running costs presented in table 7 have been calculated for the Air-Forced Ventilated Polyhouse and Naturally Ventilated Polyhouse based on a complete cultivation of tomatoes. The costs have been estimated for the Hybrid model as this model is not implemented yet, thus no references are available. It was assumed that the cost of fertilizers and pesticides would be similar between these two models as they are both conducted in soilless cultivation. The main differences are due to labor costs, management charges and power supply as the equipments are different. The main difference of labor cost between the Air-Forced Ventilated Polyhouse and Naturally Ventilated Polyhouse is the use of a vibrator for pollination in High-tech model while this operation is manual for both Hybrid and Naturally Ventilated models.

2.3. Productivity and benefits

The tomatoes are having a high fluctuation of price round the year in India. The price per Kg can vary according to the marketplace and the ability of farmer to negotiate the selling price. In order to make economic calculations, a fixed price has been determined based on the average price per Kg.

Moreover, the selling price is highly depending on the quality of the product. Three classes of quality are considered. The specificities of each class for tomato are described in Annex 3, based on the European Marketing Standards.

Table 8: Expected yield and quality in each protected structure

	Air-Forced Ventilated Polyhouse	**Naturally Ventilated Polyhouse**	**Hybrid model**
Yield total (Kg/m^2)	20	16	18
Yield after losses (Kg/m^2)	16	10	14
% Extra class	60%	25%	50%
% class I	30%	50%	35%
% class II	10%	25%	15%

The total yield and percentage of loss are based on a study case in Western Maharashtra. The yield has been estimated for the Hybrid model as being in between the Naturally Ventilated polyhouse and the Air-Forced Ventilated Polyhouse. However, as more equipments are available in the Hybrid model to control the environmental conditions compared to the low-tech model, the quality is supposed to be better with 14Kg/m^2 of tomatoes after losses compared to respectively 10 and 16Kg/m^2 for Naturally Ventilated Polyhouse and Air-Forced Ventilated Polyhouse.

Table 9: Expected benefits for each model

	Air-Forced Ventilated Polyhouse		**Naturally Ventilated Polyhouse**		**Hybrid model**	
	Quality repartition	Quality repartition	Income/m^2	Income/m^2	Quality repartition	Income/m^2
% Extra class (Rs 30/Kg)	9.6	2.5	75	288	7	210
% class I (Rs 25/Kg)	4.8	5	125	120	4.9	122.5
% class II (Rs 10/Kg)	1.6	2.5	62.5	16	2.1	21
Total Rs/m^2			**262.5**	**424**		**353.5**
Total Rs/surface			**1,050,000.0**	**610,560.0**		**353,500.0**

As shown in table 9, the expected benefits for each model is respectively 1,050,000.0Rs, 610,560.0Rs and 353,500.0Rs for Naturally Ventilated Polyhouse (1 acre), Air-Forced Ventilation Polyhouse (1440m^2) and Hybrid model (1000m^2). These benefits are based on the fixed rate determined for each category of quality. The selling price used for this study where 30Rs/Kg for extra class, 25Rs/Kg for class I and 10Rs/Kg for class II.

2.4. Economic feasibility

2.4.1. Return over production costs

Table 10: Economic ratio for the production of tomatoes (in Indian rupees)

	Air Forced Ventilated Polyhouse (1440m²)	Naturally Ventilated Polyhouse (1acre)	Hybrid model (1000m²)
Gross return/surface	610,560.0	1,050,000.0	353,500.0
Return over variable cost	384,913.1	246,780.0	198,565.0
Net return	374,113.1	216,780.0	191,065.0
BCR	2.58	1.26	2.18

The net return was calculated by subtracting the cost of cultivation from the gross return. The net return per square meter is calculated at respectively 259.8, 54.2 and 191 rupees for Air-Forced Ventilated Polyhouse, Naturally Ventilated Polyhouse and Hybrid model.

The Benefit Cost ratio (BCR) was worked out by using the formula suggested by Palaniappan (1985):

BCR = Gross return (Rs) / Total cost of cultivation (Rs).

The B:C ratio is positive for each model and is calculated at respectively 2.58, 1.26 and 2.18 for Air-Forced Ventilated Polyhouse, Naturally Ventilated Polyhouse and Hybrid model.

2.4.2. Standard model of investment

The purpose of this part is to build a standard model of investment for the Air-Forced Ventilated Polyhouse, Naturally Ventilated Polyhouse and Hybrid model. In order to reach this objective, the economic feasibility has been calculated for each model. To obtain a standard of investment for each model, the payment is assumed to be carried out in one time, without any loan or subsidies. Thus, interests and loan repayment are not included in the costs. The Pay-back period and the Return on Investment (ROI) have been determined. The results are shown in table 11.

Table 11: Economic calculations of feasibility (in Indian rupees)

	Air-Forced Ventilated Polyhouse (1440m²)	Naturally Ventilated Polyhouse (1008m²)	Hybrid model (1000m²)
Total Investment cost	10,249,179.12	718,133.78	2,143,003.06
Expected yearly benefits (net income)	110,556.48	49,192.72	174,577.45
Pay-Back period	>50	15	12
ROI	1.08	6.85	8.15

The Pay-Back Period is the time required to earn back the amount invested in an asset from its net cash flow. It is expressed in years and enables to evaluate the risk associated to the proposed project. The following formula has been used to calculate the payback period of the three models studied:

(Total investment cost/Annual net profit)

As presented in table 11, the pay-back period is calculated at respectively 15 and 12 years for the Naturally Ventilated Polyhouse and Hybrid model while it is above 50 years for the Air-Forced Ventilated Polyhouse.

The Return on Investment (ROI) ratio has been calculated by using the following formula:

(Net profit/Total investment) *100

The Return on Investment calculated for each model is respectively 1.08, 6.85 and 8.15 for the Air-Forced Ventilated Polyhouse, the Naturally Ventilated Polyhouse and the Hybrid model.

2.4.3. Study case

This part aims to present the economic feasibility of each model based on real conditions. Thus, the repayment of loan and the subsidies available for farmers in Maharashtra are included in the calculations. The calculations are based on the statement that the farmers have enough savings to cover the crop cultivation. Only a long-term loan is used to cover 75% of the investment costs, as normally operated in Maharashtra (NHB, 2019). Indeed, as mentioned by Mr. Rewar (NHB interview, Annex 4), after approval of the project from NHB, the farmer is bringing 25% of the price and can obtain a long-term loan from the bank for the remaining 75%. After construction of the polyhouse and if this one respects the BIS Standards, NHB is repaying 50% of the loan to the bank directly. During the construction, the farmer is furnishing the bills to the bank who open a special account and borrow the money to the farmer. Once the construction is completed and approved by the National Horticultural Board (NHM), 50% of the total cost is transferred directly to the account. The repayment planning is then defined for the 25% of total cost remaining on the loan account. The terms of loans are detailed in table 12 for each model.

Table 12: Terms of long-term loans and availability of subsidies in Maharashtra
Source: NHB, farmers and Indian bank

	Air Forced Ventilated Polyhouse	Naturally Ventilated Polyhouse	Hybrid model
Total investment cost	10,249,179.12	718,133.78	2,143,003.06
Duration of loan	20	10	10
Rate of interest	10%	18%	18%
Rate of subsidy	50%	50%	50%

The duration of loan has been settled at 10 years for the Naturally Ventilated Polyhouse and the Hybrid model. As the investment cost is higher for the Air-Forced Ventilated Polyhouse, the duration of loan is defined at 20 years. The rate of interest is based on the current rate from the Indian bank with respectively 18% and 10% for 10 years and 20 years of repayment.

The interest is calculated using the following formula, with a residual value estimated at 0:

(Investment + residual value)/2 x interest percentage

The calculations are shown in table 13.

Table 13: Economic calculations of feasibility (in Indian rupees) including loan repayment, interests and subsidies

	Air-Forced Ventilation Polyhouse (1440m²)	Naturally Ventilated Polyhouse (1008m²)	Hybrid model (1000m²)
Initial investment from farmer	2,562,295.0	179,533.0	535,751.0
Annual repayment of loan and interests without subsidies	768,688.0	102,334.0	305,378.0
Annual repayment of loan and interests including subsidies	256,229.0	34,111.0	101,793.0
Annual net income without subsidies	-658,132.0	-53,141.0	-130,801.0
Annual net income with subsidies	-145,673.0	15,082.0	72,784.0
Pay-Back period without subsidies	n/a	n/a	n/a
Pay-Back period with subsidies	n/a	12	7
ROI without subsidies	-25.69	-29.60	-24.41
ROI with subsidies	-5.69	8.40	13.59

As shown in table 13, the annual net income including the repayment of loans and interests is negative for each model when no subsidies are integrated. The payback period and return on investment are thus also negative. When 50% of subsidies are deducted from the total investment cost, the annual income is negative for the Air-Forced Ventilated Polyhouse, and at respectively 15,082.0 and 72,784.0 rupees for Naturally Ventilated Polyhouse and Hybrid model. The payback period and return of investment are calculated respectively at 12 years and 8.40% for the Naturally Ventilated Polyhouse, 7 years and 13.59% for the Hybrid model.

3. Efficiency of production

3.1. Workforce

The total workforce required has been calculated in terms of labor cost for the high-tech model and the low-tech model at respectively 42 and 53 Rupees per square meter. The repartition of labor cost is shown in Figure 6 in percentage of total labor cost per activity. The workforce required for the Hybrid model has been estimated at 44 rupees per square meter.

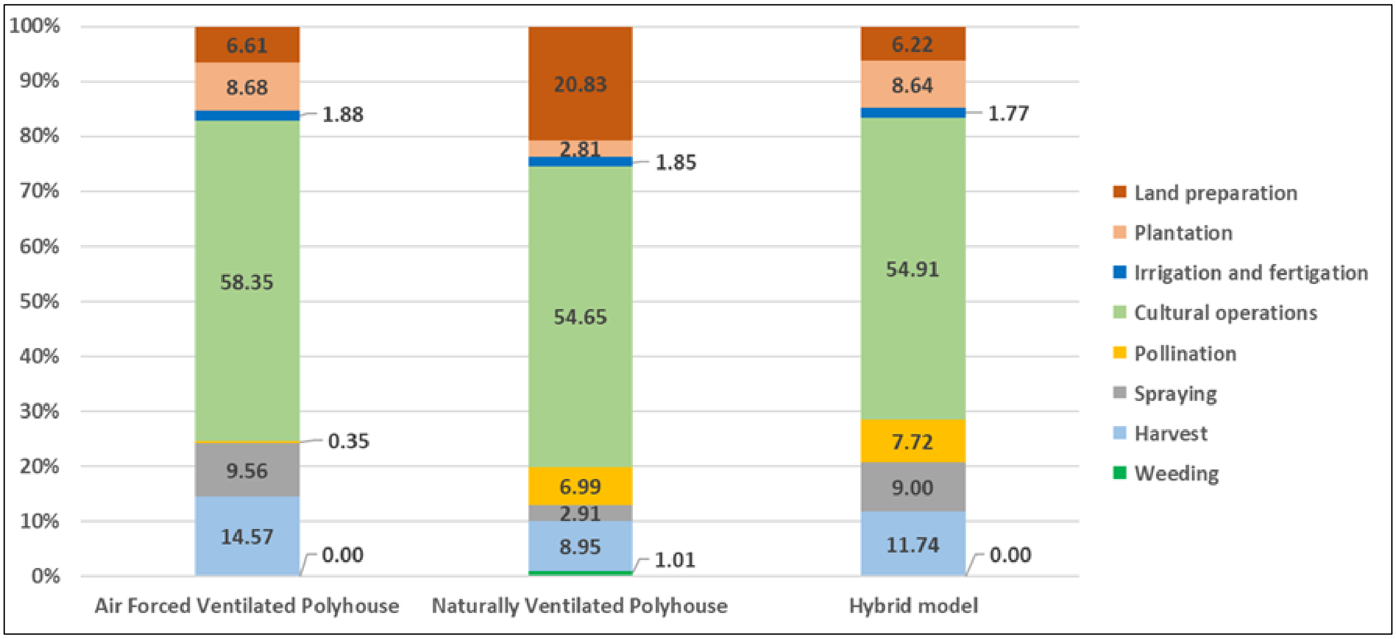

Figure 7: Repartition of labor cost for each model

The main differences observed between the three models are for the land preparation and plantation, the pollination and spraying activities. No weeding is required in both high-tech and hybrid model as cultivations are conducted in substrate. The category of land preparation includes the preparation and placement of grow bags on the rows for High-tech and Hybrid models, the placement of drippers being processed during the plantation. For the Low-tech model, the land preparation includes the disinfection of soil, the incorporation of products for soil structuration and fertility (vermicompost, humic acid, red soil) and raising of beds. The placement of online drippers is included in this category also. The use of vibrator machine in High-tech model enables a low cost of pollination with 0.15 rupees per square meter compared to 3.75 and 3.45 in Low-tech model and Hybrid model respectively. The category spraying includes many sprays with a small amount of product for High-tech and Hybrid models, whereas small number of sprays are used in Low-tech model with a higher amount of product. The total cost of labor for treatment in rupees per square meter was determined at 4.02 for High-tech and Hybrid models, and 1.56 for the Low-tech model.

3.2. Use of inputs

This part aims to present the differences of inputs between the three models of cultivation compared in this study. The requirements in terms of workforce, water, fertilizers and pesticides have been calculated based on current practices in Maharashtra.
The measurement of losses, which requires many instruments and is time consuming, are thus not commonly operated in India from others than research institutes or private companies to answer a specific question. For this reason, the results presented in this study for the losses aspects are based on literature research.

3.2.1. Water and fertilizers requirements

The total amount of water used has been determined at 756,000.00 liters for 1,440.00m² in High-tech model and 544,320.00 liters for 1,008.00m² in Low-tech model. These assumptions are based on current practices, with an average of respectively 2.5L/m²/day and 3L/m²/day in High-tech and Low-tech models. The amount of water taken for the Hybrid model has been esteemed at 2.75L/m²/day with a total of 577,500.00 liters for 1,000.00m². This estimation is based on the statement that more losses are occurring in Hybrid model than High-tech. Indeed, as mentioned by Londra (2010), the evapotranspiration rate highly depends on greenhouse environmental conditions, and those are less controlled in Hybrid model than High-tech model due to less equipments.

The amount of fertilizers used has been calculated from current farming practices at 38.45 rupees per square meter for Low-tech model and 38.80 rupees per square meter for High-tech and Hybrid models. As the system of fertigation is the same, no difference has been estimated in terms of amount of nutrients for High-tech and Hybrid models. The costs of fertilizers are presented in Figure 7 for each model.

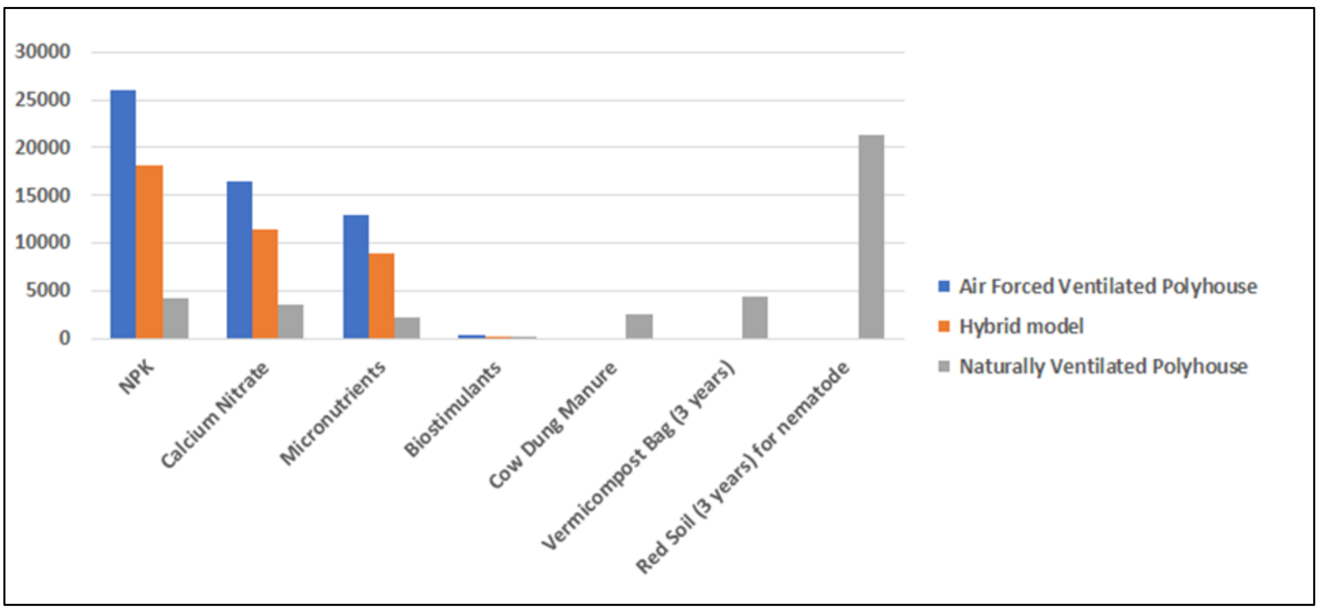

Figure 8: Cost of fertilizers used for each model

As shown in the figure 7, the amount of nitrogen, phosphorus, potassium and micronutrients is higher in High-tech and Hybrid model. The main products used in Low-tech model are oriented to the soil structuration with 4,000.0Kg of cow dung manure, 4.5Kg of biostimulants, 1,500.0Kg of vermicompost and around 100 brass of red soil every three years.

Based on the calculations from Jisha Chand (2014), the efficiency of use for water has been calculated according to the following formula:

WUE= Weight of marketable produce of the crop (kg/m²) / Amount of water used (Liters/m²)

Table 14: Water Use Efficiency in each model of cultivation

Structure	Yield (Kg/m²)	Amount of water (L/m²)	WUE (%)
Air-Forced Ventilated Polyhouse	16	525	3.05
Naturally Ventilated Polyhouse	10	540	1.05
Hybrid Model	14	577.5	2.42

As shown in table 12, there are differences between the water use efficiency in each model. Indeed, the percentage of WUE is calculated at 3.05 for High-tech model, 1.05 for Low-tech and 2.42 for Hybrid model.

- **Losses occurring in irrigation and fertigation**

Even in soilless cultivation systems, according to Linden (2016) and Incrocci (2014), irrigation represents a very large and potentially important loss of nutrients even in soilless irrigation, as a surplus of 20% to 50% of the plant's water uptake in each irrigation cycle is often recommended.
Many institutions are working on developing various models of water efficiency in order to improve water use in irrigation, but these models are not yet commercialized (Levidow, 2017; Pawlowski, 2017)).
As for Zeng (2009) and Sezen (2010), the exact time and volume of irrigation are probably the most important factors to manage efficiently irrigation and to save water.

Harmanto et al. (2005), working with soil-based greenhouse tomatoes in a tropical environment, showed that drip irrigation could save 20 to 25% more water than an open field drip irrigated farming system.

Yet, the management or irrigation in substrate requires a much more accurate control than in soil, as the substrate has a very little nutrient buffering capacity (Gallardo, 2013).
However, the restricted root volume can have a negative effect on the supply of nutrients to the plants as the amount water in the substrate is decreasing faster than in soil. (Raviv, 2008 and Asaduzzaman, 2015).
In addition, changes are induced in air and water retention from substrates when they are used for longer periods than one growing season (Warren, 2005 and Vox, 2010).
As mentioned by Kläring (2001), the main strategy in surface micro-irrigation system is to supply the nutrient solutions with a surplus of 30% to 50% of water. This is due to the fact that there is always a risk in matching irrigation supply to crop evapotranspiration, especially since sudden changes in weather conditions or climate control in the greenhouse (e.g. ventilation) may affect the water uptake by the plants. (Baille, 1994).

3.2.2. Crop protection sprays

The participation of pesticides in the variable cost has been calculated for each model with the following formula:

% of pesticide= Total cost of treatments (Rs)/ variable costs (Rs)

As no study has been conducted on Hybrid model yet, it is assumed than the amount of pesticides used is the same as the High-tech model.

Table 15: Representativity of pesticides in the variable costs

Structure	% related to pesticide
Air-Forced Ventilated Polyhouse (1440m²)	3.33
Naturally Ventilated Polyhouse (1008m²)	10.31
Hybrid Model (1000m²)	3.37

The results presented in Table 13 show that the cost of pesticide is more impacting the total variable costs for the Low-tech model than the High-tech and Hybrid models.

Based on the current production costs in Maharashtra for the year 2017, the cost per square meter of pesticides is respectively 20.7 and 5.22 rupees per square meter for Low-tech and High-tech model. The proportion of pesticide used per category of spray is shown in Figure 8.

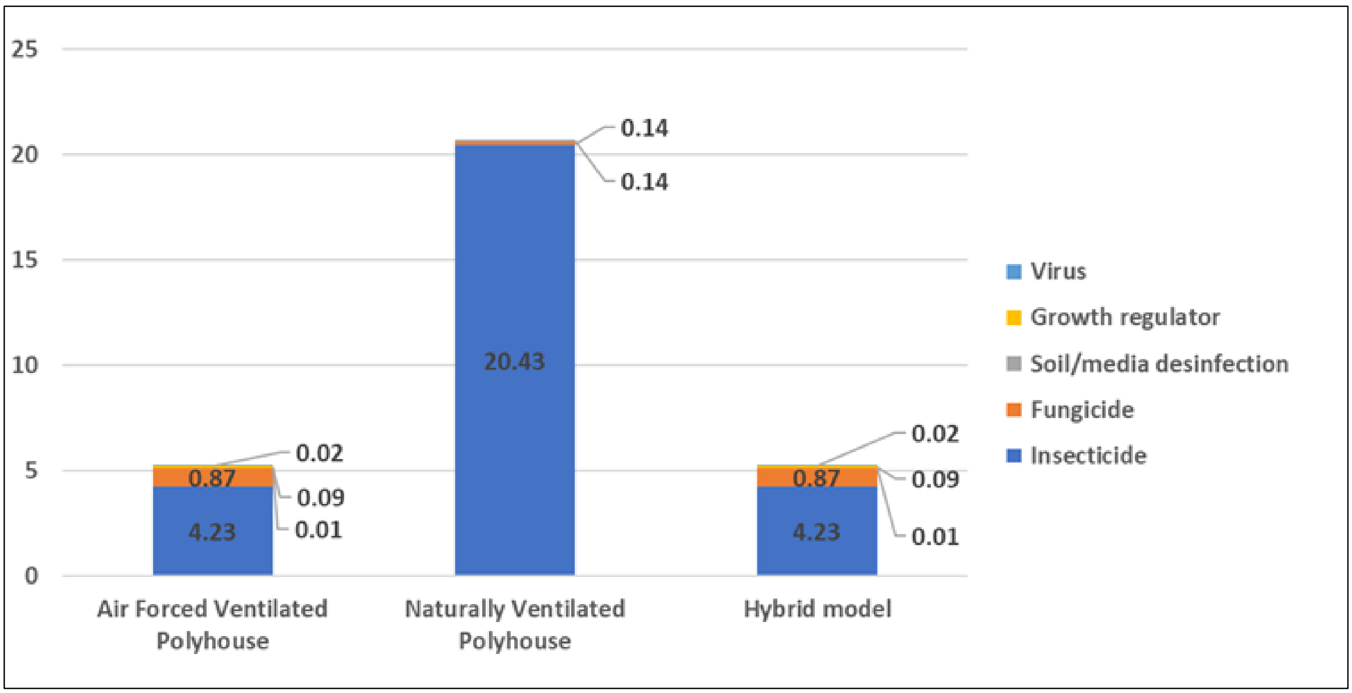

Figure 9: Repartition of spraying costs per square meter per target

For each model of cultivation, insecticides are the main pesticides sprayed for the tomatoes. No growth regulator nor virus control product are needed for the Low-tech model. The total cost related to fungicide is higher in High-tech and Hybrid models than in Low-tech model with respectively 1,251.0; 869 and 137 rupees for High-tech model (1,440.0m²), Hybrid model (1,000.0m²) and Low-tech model (1,008.0m²). In the Low-tech model, 97% of the insecticides cost is related to nematodes control with a total of 20,333.0 Rupees (Neem cake and Neemazal).

- **Need of spray according to the conditions and eventual losses**

First of all, as mentioned by Smith (2019), it is important to recognize conditions that discourage one group of pests can often favor another. Moreover, protected structures which are screened can physically exclude many insect pests but are also sheltering the insect pests inside the structure from their enemies (Smith, 2019).

Differences in pests and diseases management are also observed between soil and soilless cultivation. Indeed, due to its content of beneficial microflora, the soil has the capacity to dampen the effects of soil-born pathogens (Jarvis, 1991). The buffer capacity of soilless media is lower than soil, thus in case of disease outbreak into the plant roots the natural control will be low or inexistent (for example in sterilized media).

As studied by Schnitzler (2004), soil cropped greenhouses have more evapotranspiration than with soilless culture. Thus, more ventilation is required to replace the saturated air by dry air, resulting in a decreased relative humidity. This lower relative humidity in the air can reduce the risk of fungal diseases especially Botrytis and Powdery mildew compared to soilless cultivation if ventilation is correctly performed. However, too low humidity in the greenhouse environment helps the population of several insect pests. (Schnitzler, 2004).

In general, plants grown in soilless culture may be attacked by the same pests and diseases as traditional cultivation in soil but with a different frequency and degree of severity. This for the soil-born diseases and root infesting pathogens, but also for the air-born diseases, because the microclimate environment has changed in soilless cultivation (Göhler and Molitor, 2002).

4. Perception of technology by Indian farmers

As mentioned by the National Horticultural Board (Annex 4), the state of Maharashtra is one of the most developed state in terms of technology for agriculture. The farmers are demanding more and more financial support to NHB, but also technical support. The surface and demand for modern protected cultivation is increasing to produce high value vegetables as tomato, capsicum and cucumber (cash crops) but also parsley, celery, broccoli and leafy vegetables. The controlled conditions of production enable a production round the year with good rates in off-season, and the quality of products enable farmers to reach market target as 5 stars hostel and thus having better profits.

4.1. Position of farmers toward modern technology

During the survey on position of farmers toward modern technology, five closed questions have been asked through the questionnaires. The willingness of implementing modern technology and modernizing the farm with or without subsidies have been determined. As investing into technology is a consequent investment, the position of farmers toward bank and loans have also been asked. The last point included in the survey was the capacity of the farmer to run a production in a polyhouse. The results are shown in figure 10.

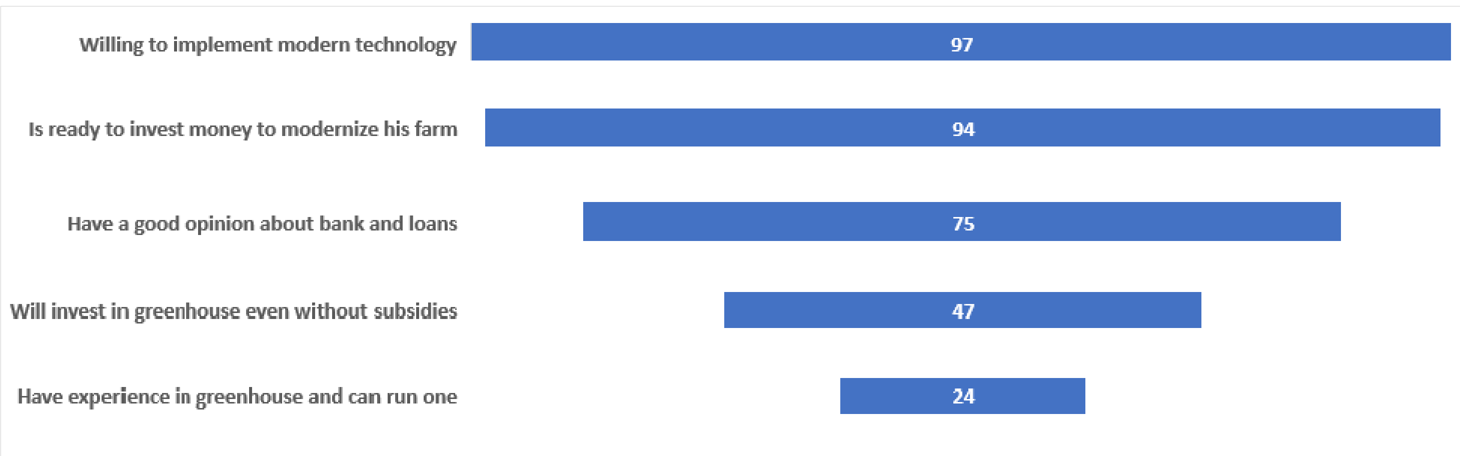

Figure 10: Results of questionnaires to farmers (in percentage)

On the 62 respondents for the survey, 60 people declared being willing to implement modern technology into their farm. 34 people on the 36 respondents are ready to invest money in order to modernize their farm. Among this 34 people, 16 are willing to invest even without subsidies from the government. 27 people on the 36 respondents affirmed having a good opinion about bank and loans and 10 people on 41 respondents declared having experience in greenhouse cultivation and being able to run one. As it is important to know the knowledge of farmers in order to determine the relevance of modern technology into the cultivation system, the level of knowledge in modern technology has been asked to the farmers. Th results are shown in figure 11.

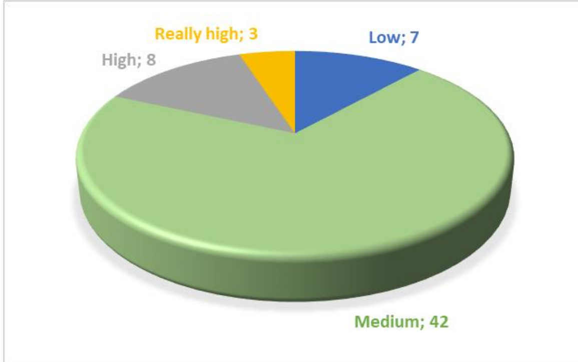

Figure 11: Farmers Knowledge about modern farming technology

On the 60 respondents to the question related to their knowledge, 70% of farmers esteemed having a medium knowledge about modern technology. Respectively 12%, 5% and 13% of farmers esteemed their knowledge as low, really high and high. Through an open question the opinion of farmers about technology have been studied. The main results have been gathered into categories which are presented in figure 12.

Figure 12: Opinion of farmers about modern technology for agriculture purpose

The opinion of farmers has been collected from a total of 49 respondents. Among these answers, 32 people mentioned that adopting modern technology into the cultivation system enables to increase the productivity, 18 people declared it enables to save time during cultural operations and 13 people declared that it was necessary to adopt modern technologies in farming systems and it should be developed in each farm. 4 respondents declared that implementing new technology was costly due to the high investment cost, and 3 respondents mentioned a need of proper knowledge and trainings to use modern technologies. Few comments have been added from the respondents. One mentioned that implementing modern technologies is beneficial for farmers as it increases the income and thus the living standards. Another declared finding difficult to integrate modern technology into farming systems as it requires a lot of knowledge.

Two people mentioned that adopting modern technology is necessary to change from subsistence agriculture to commercial level, and that it enables to minimize the post-harvest losses. Three respondents declared that there is a need of research to develop the available technologies in terms of feasibility (2 people), adaptability to the climatic conditions (1 person) and systems of production (1 person). According to one farmer, adoption of modern technologies enables maximum returns if it is applied wisely as per available resources and requirements. Finally, one farmer mentioned that technologies are beneficial, however the lack of proper structure will result in losses whatever technological equipment is used.

4.2. Constraints and opportunities in adoption of technology

Table 16: Main constraints and opportunities for adoption of modern technology by Indian farmers
Sources: Prabhakar et al, 2017; Singh, 2014

Constraints	**Opportunities**
Environmental: - Highly fluctuating weather conditions - Poor drainage of soil and low soil fertility status - Occurrence of pests and diseases Technical: - Highly knowledge and skills intensive - Availability of quality seeds and planting materials - Limited and irregular supply - High cost of skilled labor - Lack of effective supervision Economical: - High initial cost of investment - Complexity of loan procedures - Lack of awareness about credit and subsidies availability - Absence of crop insurance scheme for flowers and vegetables - Low risk bearing capacity Marketing : - Fluctuations in marketplace - Existence of middlemen malpractices - Lack of specialized supply chain including cold chain - Lack of coordination of farmers	Environmental: - Better reaction capacity to weather fluctuations with controlled environment - Reduction of soil-born diseases and nematodes impact with soil-less cultivation - Controlled environment enables to avoid conditions favorable to pests and diseases Technical: - Increasing availability of trainings and demonstrations for farmers through NHM schemes, KVK and private institutions - Development of R&D for cultivars adapted to protected cultivation Economical: - Extension of subsidies available both for initial investment in polyhouse and for introducing technologic equipments - Development of institutions to help farmers in the process of getting loans and subsidies - Trend of collective investment between farmers Marketing : - Off-seasonal production in controlled environment polyhouse enables to get better rates - Development and extension of Farmers Producers Organizations (FPO) Farmers Producers Companies (FPC) giving more power to the farmers on the market and helping in the organization of supply

As shown in table 14, the Indian farmers in the State of Maharashtra are facing many constraints to adopt technology in their cultivation system. Indeed, additionally to the high investment costs, the availability of package of practices for cultivation of crops under polyhouse is either limited or requires lot of modification to suit their agro-ecological system and socio-economic conditions (Prabhakar, 2017). Moreover, the farmers are becoming highly dependent to formal sector for quality planting materials, especially private seed companies (Manjunatha et al, 2013). The study from Prabhakar (2017) also revealed that the difficulty of grading the produce at the production level and the lack of post-harvest facilities were a major constraint in fetching good prices from market.

As mentioned by Sonneveld (2000, cited by Hussain et al, 2004), application of technology on commercial scale requires technical knowledge and high initial capital expenditure, which are even further if the soilless culture is combined with controlled environment. Finally, energy inputs are necessary to run the system (Van Os et al.,2002). Farmers of Maharashtra have reached an advanced stage of polyhouse cultivation and are currently expanding the area under polyhouse cultivation. Thus, power supply is considered as a critical input (Prabhakar, 2017).

Despite these constraints, many opportunities are available to enhance the adoption of technology by Indian farmers. Through different schemes developed by the Indian Government, several trainings are directly available for farmers about technical knowledge and know-how on protected cultivation but also on general skills as monitoring, supervising, managing, marketing and so on. Agriculture department officials suggested reforms in subsidy schemes for polyhouse cultivation, with expanding the basket of beneficiaries under subsidy scheme along with increasing the existing ceiling limits for area under polyhouse cultivation. Working Group Report on Development of Protected Cultivation in Haryana (2013) suggested that innovative marketing approaches such as cluster and cooperative based marketing will increase the bargaining capacity of Indian farmers, thereby giving them power to decide the price of their products in the market.

Moreover, Research and Development initiatives aim at developing low-cost designs and reducing the cost of erection for polyhouses and the costs of cultivation. Private seeds companies are also settling in India to develop and commercialize adapted and affordable seeds for protected cultivation, as the potential of Indian production is high and the scope for international companies to sell their varieties is constantly increasing (Enza Zaden representant, 2019).

Chapter 4: Discussion of results

The aim of this study is to demonstrate that adopting modern technology in farming can improve the long-term benefits for farmers while reducing the inputs and the workforce required, and to increase the productivity and quality of products. For this purpose, an analysis of three models of protected cultivation as be conducted based on their economic feasibility and efficiency of work, and the perception of farmers about modern technology has been studied to determine the scope of its implementation in the State of Maharashtra.
The three models studied were the Air-Forced Ventilated Polyhouse (High-tech model), the Naturally Ventilated Polyhouse (Low-tech model) and the Hybrid model (Mid-Tech polyhouse).

In the first Chapter, the main findings about economic feasibility are that the High-tech model enables the best productivity and quality of vegetables, with a B:C Ratio superior to the other models (2.58 compared to respectively 1.26 and 2.18 for Naturally Ventilated Polyhouse and Hybrid model). However, when the repayment of loan is considered, the profitability of the high-tech model is negative due to the high cost of investment. Indeed, many of the structural components are imported from Europe, and thus more costly due to the currency and import duties. Moreover, when the subsidies provided by the government for the establishment of polyhouse are not included, none of the three models are profitable as the costs of production, interests and repayment of loan are higher than the annual gross return. As mentioned by Mr. Rewar (National Horticultural Board), the production of tomatoes in polyhouse is often not profitable in Maharashtra as only one cultivation is conducted annually (around 8 months of production for tomato), which does not enable to cover the whole expenditures.

Therefore, when 50% of subsidies are included into the economic calculations, the Naturally Ventilated Polyhouse and the Hybrid model appear to be profitable with a pay back period and a return of investment (ROI) of respectively 12 years and 8.4 ROI for the Naturally Ventilated Polyhouse and 7 years and 13.59 ROI for the Hybrid model.

However, different factors can influence these results as the farmers are facing high fluctuations of rates according to the period of production, the availability of market and their ability to negotiate the selling price. In addition, the rate of interest and the terms of loan repayment vary according to the bank and the farmers economic capacity of repayment, thus the calculations may vary according to the context. In order to increase the accuracy of results, different rates should be integrated to the calculations of economic feasibility.

In the second chapter, the efficiency of production has been determined for each model in terms of workforce and inputs required and the losses occurring. The main differences observed between the Low-tech, Mid-tech and High-tech models in terms of labor requirements are due to the land preparation and plantation, the pollination and spraying activities. The cost of workforce is higher in the Naturally Ventilated Polyhouse as the land preparation and plantation are more time consuming. The introduction of vibrator in the High-tech model enables to reduce the cost of pollination which is operated manually for the other models. Moreover, the spraying activity vary between the models as the frequency of spray is higher in High-tech and Hybrid models than in Low-tech model. The efficiency of water use (WUE) is better in the high-tech model due to the accuracy enabled by the soilless cultivation system and the controlled environment with a ratio of 3.05 compared to respectively 1.05 and 2.42 for the Naturally Ventilated Polyhouse and High-tech model. This result is confirmed by TNAU (2013) who mentioned 39% of water saving and 50% increase of yield between drippers and surface micro-irrigation for tomatoes in Indian context.
The cost related to fertigation is similar between each model but with a different target. Indeed, most of the fertilizers used in Naturally Ventilated Polyhouse are oriented to the soil structuration while their role in the High-tech and Mid-tech models is to maximize the crop potential by bringing mostly nitrogen, phosphorus and potassium directly to the rootzone.

More losses are occurring for the Low-tech model as a surplus of inputs is often recommended in soil cultivation system to balance the evaporation and losses in soil. Soilless cultivation has the major advantage that the supply of water and nutrients can be operated according to the plant requirements directly to the rootzone and adapted to each stage, which increase their efficiency.

The cost of pesticide is higher in Naturally Ventilated Polyhouse due to the important use of insecticides to control the nematodes. Indeed, this is the major problem faced by farmers in soil cultivation in the State of Maharashtra as nematodes can cause an overall average yield loss up to 60% in protected cultivation of major horticultural crops, including tomatoes (Manjunatha, et al. 2017).

These results are similar to those from Suryawanshi (2016) and Nimbrayan *et al* (2018) who mentioned that in controlled conditions the climate and diseases do less affect the production level, which increases the productivity and ensure a better quantity and quantity. However, the reliability of the results obtained is affected by the numerous estimations, especially for the Hybrid model. Due to the lack of scientific references for the fluctuations of climatic conditions in Maharashtra and the losses occurring, few components are not integrated to the study as the evaporation rate, the capacity of crop to uptake the water and nutrients and the permeability of the structure in terms of air flow and thus ventilation. Losses of water, fertilizers and chemical should be measured to get primary data. There is a need of research to determine the exact amount of inputs which could be saved by using specific equipments.

In addition, as detailed by Norton (1976), the amount of pesticides used is highly depending on farmers perception and their different levels of acceptance (threshold level). A high variation can also be observed according to the conditions of the year. To maximize the efficiency of inputs, it is necessary to monitor each biotic and abiotic component, and thus to have a good understanding and know-how to adapt each action to the target (e.g. use of pesticides) and to act at the right timing.

In the third Chapter, the perception of farmers about modern technology in farming systems has been studied. The objective was to determine the relevance and the scope of implementing technology into the cultivation systems in the State of Maharashtra. The main findings of this study are the willingness of farmers to invest into modern technology and to modernize their farm. As observed during the collection of questionnaires, the farmers are seeing many advantages and profits while implementing technologies. It also appears that the knowledge and skills are important factors to overcome for implementing technology in the cultivation systems. Indeed, 70% of farmers esteemed their knowledge as medium, and 24% of the respondents don't feel able to run a polyhouse. However, these results are depending on the subjectivity of each farmer, and their estimation of knowledge is depending on their own references as no criteria have been defined to measure it. Due to this lack of objectivity, the reliability of these data might be inaccurate, but can be used as an indicator of farmers' confidence toward technological items.

The study shows that less than 50% of the farmers are willing to invest without subsidies. This result is coherent according to results of the economic feasibility presented in the first Chapter and join the conclusions of Jadhav and Rosentrater (2017), who demonstrated that the high initial cost is one of the greatest worries in the adoption of the technology by the farmers.

Many of the respondents affirmed that implementing modern technology enables to increase the profits while increasing the productivity and reducing the expenditures. These results are confirmed by the analyze of the efficiency of production presented in the second Chapter.

Conclusions and Recommendations

The objective of this study was to demonstrate the relevance of implementing modern technology in Indian farming systems for the State of Maharashtra while comparing three different models to determine the most suitable for Indian farmers.

The investment costs and running costs are calculated at respectively 10,249,179.12 rupees and 164.20 rupees per square meter for the Air- Forced Ventilated Polyhouse, 718,133.78 rupees and 208.31 rupees per square meter for the Naturally Ventilated Polyhouse and 2,143,003.06 rupees and 162.44 rupees for the Hybrid model. The economic feasibility has been calculated for each model and shows a better profitability of the High-tech model when the repayment of loan is not included, with a net return of 424 rupees per square meter as the productivity and quality is higher than the Hybrid model (353.5 rupees per square meter) and the Naturally Ventilated Polyhouse (262.5 rupees per square meter). Due to the high cost of investment, none of the three models is profitable when no subsidies are integrated in the repayment of loan. In case of 50% subsidies provided by the government, the Hybrid model would be the most suitable for Indian farmers as the payback period is calculated at 7 years compared to 12 years for the Naturally Ventilated Polyhouse, with a ROI of 13.58 against 8.4.

The Air-Forced Ventilated Polyhouse and Hybrid models have a better efficiency of production due to the soilless cultivation which enables to reduce the workforce required and the inputs as they are directly provided to the rootzone according to the plants requirements with minimizing the losses compared to soil cultivation in the Naturally Ventilated Polyhouse. As more equipments are included in the high-tech model to control the environment, its efficiency is higher than the other models.

As shown by Prabhakar (2017), many opportunities are available to enhance the adoption of technology by Indian farmers. The survey conducted during this study shows a high willingness from farmers to implement modern technology in their cultivation system (97% of the respondents), to invest and to modernize their farm (94% of the respondents). The main limitations observed are the cost of investment if no subsidy is provided by the government, and the constraint of farmers knowledge to adopt modern technologies which is decreasing due to the development of trainings from public and private institutes.

According to these main conclusions, the Air-Forced Ventilated Polyhouse appears to have a better production efficiency but is not profitable due to its high cost of investment. Thus, the Hybrid model which also includes modern technology at a more affordable cost would be the most suitable model for Indian farmers in Maharashtra.

These results can be used in the decision process of implementing a protected structure and in the elaboration of a business plan by Indian farmers as it gives a cost and profitability estimation. The efficiency of production calculated for each models and the survey on the perception of Indian farmers show that implementing modern technologies into Indian farming systems in the State of Maharashtra is relevant, as it can improve the farmers benefits, reduce the use of inputs and workforce required while increasing the productivity and quality of vegetables.

In order to enhance the adoption of modern technology by Indian farmers, there is a need from private and public institutes to develop the trainings activities for improving the skills and knowledge required at farmers level. The Hybrid model presented in this study should be implemented at first research level and, according to the calculations operated on real conditions, be implemented at farmers level. Finally, there is a further need of research to develop affordable technologies adapted to the socio-economic and environmental conditions of Maharashtra.

References

Anonymous, 2004 “Indian Council of Agricultural Research” Agricultural Research Data Book,ICAR

Anonymous, 2019 “National Horticultural Board” Agricultural Department of Indian Government

APEDA, 2015. “Fresh fruits and vegetables” Ministry of Commerce and Industry, Government of India, New Delhi URL: http://apeda.gov.in/apedawebsite/six_head_product/FFV.htm (Consulted the 13/01/2020)

ASADUZZAMAN, M.D. et al. 2015. “Influence of Soilless Culture Substrate on Improvement of Yield and Produce Quality of Horticultural Crops” Soilless Culture-Use of Substrates for the Quality Horticultural Crops; IntechOpen Limited: London, UK; pp. 1–31.

BAILLE, M.; BAILLE, A. and LAURY, J.C. 1994. “A simplified model for predicting evapotranspiration rate of nine ornamental species vs. climate factors and leaf area” Sci. Hortic, 59, pp. 217–232

BHATNAGAR, P.R. 2014 “Strategies for Protected Cultivation for Small and Marginal Farmers in India” Agriculture: Towards a New Paradigm of Sustainability ISBN: 978-93-83083-64-0 158

BIJAY, K. 2017 “Technical standards for Naturally Ventilated, Fan & Pad Green House and Shade Net House” Protected cultivation under NHB Scheme (Technical Standard No. NHB-PH-Type 02-2011)

FAO, 2020. “India at a glance” URL: http://www.fao.org/india/fao-in-india/india-at-a-glance/en/ (Consulted 15/01/2020)

FOSTER, A.D. and ROSENZWEIG, M.R. 2010 “Microeconomics of technology adoption” Economic Growth Centre Discussion Paper No. 984. Yale University: New Haven USA.

GALLARDO, M. THOMPSON, R.B. and FERNANDEZ, M.D. 2013. “Water requirements and irrigation management in Mediterranean greenhouses: The case of the southeast coast of Spain” Good Agricultural Practices for Greenhouse Vegetable Crops; Plant Production and Protection Paper 217; FAO: Rome, Italy; pp. 109–136

GOH. 2013. Working Group Report on Development of Protected Cultivation in Haryana. Haryana Kisan Ayog, Government of Haryana, pp 1–66.

GÖHLER, F. and MOLITOR, H.D. 2002. “Erdelose Kulturverfahren im Gartenbau” Eugen Ulmer Verlag, Germany. Nachrichtenblatt Dtsch. Pflanzenschutzdienst 43 (4); pp. 69-73

HARMANTO, S. et al. 2005. “Water requirement of drip irrigated tomatoes grown in greenhouse in tropical environment” Agricultural Water Management, 71, pp. 225–242

HUSSAIN, A. et al. 2004 “A Review On The Science Of Growing Crops Without Soil (Soilless Culture) –A Novel Alternative For Growing Crops” International Journal of Agriculture and Crop Sciences, Vol., 7(11), 833-842

INCROCCI, L. et al. 2014. « Substrate water status and evapotranspiration irrigation scheduling in heterogenous container nursery crops” Agricultural Water Management, 131, pp. 30–40

JADHAV. HT, ROSENTRATER. KA. (2017) “Economic and environmental analysis of greenhouse crop production with special reference to low cost greenhouses: A Review” An ASABE Meeting Presentation. 1701178 :1-6.

JARVIS, B. 1991. “Does Hydroponic Production Solve Soilborne Problems?” American Vegetable Grower, 10, pp.54-57

JISHA CHAND, A.R. 2014 “Nutrient Use Efficiency and Economics of Salad Cucumber Using Drip Fertigation in Naturally Ventilated Polyhouse” IOSR Journal of Agriculture and Veterinary Science, Volume 7, Issue 12 Ver. II, PP 22-25

KLÄRING, H.K. 2001. “Strategies to control water and nutrient supplies to greenhouse crops” A review. Agronomy, 21, pp. 311–321

KUMAR, P. et al. 2016 “Economics analysis of tomato cultivation under poly house and open field conditions in Haryana, India” Journal of Applied and Natural Science 8 (2): 846 – 848

LEVIDOW, L. et al. 2014. “Improving water-efficient irrigation: Prospects and difficulties of innovative practices.” Agricultural Water Management, 146, pp. 84–94

LONDRA, P.A. 2010. “Simultaneous determination of water retention curve and unsaturated hydraulic conductivity of substrates using a steady-state laboratory method” Horti Science 45, 1106–1112

MANJUNATHA, B.L; RAO, DUM; DASTAGIRI, MB. 2013. “Trends in seed production, growth drivers and present market status of Indian Seen Industry: An analytical study” Indian Journal of Agricultural Sciences 83(3) pp. 315-320.

MANJUNATHA, T.G. RAI, A.B. and SINGH, B. 2017 “Root Knot Nematode: A Threat to Vegetable Production and its Management” IIVR Technical Bulletin No. 76, IIVR, Varanasi, pp.32

MURTHY, D.S. et al, 2009. « Economic feasibility of vegetable production under polyhouse: A case study of capsicum and tomato” Journal of Horticulture Sciences, Vol. 4 (2): 148-152, 2009

NIMBRAYAN, P.K. et al. 2018 “A Review on Economic Aspect of Protected Cultivation in India” Chapter 3. 43-59

PAWLOWSKI, A. et al. 2017. “Evaluation of event-based irrigation system control scheme for tomato crops in greenhouses” Agricultural Water Management, 183, pp. 16–25

PHOOKAN, D.B. and SAIKIA, S. 2003 “Vegetable production under naturally ventilated plastic house cum rain shelter” Plasticulture Intervention for Agriculture Development in North Eastern Region, Edt. by K.K. Satapathy and Ashwani Kumar, pp. 127-141.

PRABHAKAR, I. et al. 2017. “Constraints in adoption and strategies to promote polyhouse technology among farmers: A multi-stakeholder and multi-dimensional study” Indian Journal of Agricultural Sciences 87 (4): 485–90

RAVIV, M and LIETH, J.M. 2008. “Significance of Soilless Culture in Agriculture” Soilless Culture, Theory and Practice; pp. 1–10

REHMAN, A. and HUSSAIN, I. M. 2016 “Modern Agricultural Technology Adoption its Importance, Role and Usage for the Improvement of Agriculture” American-Eurasian J. Agric. & Environ. Sci., 16 (2): 284-288

SANWAL, S.K. et al. 2004 « Vegetable production under protected cultivation in NEH region: problems and prospects” ENVIS Bulletin: Himalayan Ecology, Vol. 12(2), 2004

SCHNITZLER, W.H. 2004 “Pest and disease management of soilless culture” ISHS Acta Horticulturae 648: South Pacific Soilless Culture Conference - SPSCC

SEZEN, S.M. et al. 2010. “Effect of irrigation management on yield and quality of tomatoes grown in different soilless media in a glasshouse” Science Research Essays, 5, pp. 41–48.

SINGH, B. 1998 “Vegetable production under protected conditions: Problems and Prospects” Indian Soc. Veg. Sci. Souvenir: Silver Jubilee, National Symposium Dec. 12-14, 1998, Varanasi, U.P. India pp. 90.

SINGH, B. et al. 1999. “Ladakh Mein Sabjion Kei Sanrakshit Kheti” Regional Research Laboratory of DRDO, Leh. Pub. By D.R.D.O., Leh. Pub. By D.R.D.O. 56 A.P.O.

SINGH, R.K.P. et al. 2014 “A study n Adoption of Modern Agricultural Technologies at Farm Level in Bihar” ICAR-RCER, Patna. Munich Personal RePEc Archive

SMITH, H.A.; VALLAD, G.E. and BIELINSKI, M.S. 2019 “Integrated Pest Management in Protected Structures I: Basic Principles and Scouting” Entomology and Nematology Department, Institute of Food and Agricultural Sciences (IFAS), University of Florida

SONAWANE, Y. R. et al, 2016 “Environment monitoring and control of a poly house farm through Internet,” in Proceedings of 2nd Intelligent Computing and Information and Communication, IIT Kanpur

SONNEVELD, C. 2000. Effects of salinity on substrate grown vegetables and ornamentals in greenhouse horticulture. PhDThesis, University of Wageningen, The Netherlands

SURYAWANSHI, A.A. 2016 “Sustainable Agriculture in Maharashtra–A Case Study of Satara District” Advances in Economics and Business Management (AEBM) p-ISSN: 2394-1545; e-ISSN: 2394-1553; Volume 3, Issue 5; April-June

TNAU. 2013 “Irrigation management: micro irrigation” http://agritech.tnau.ac.in/agriculture/agri_irrigationmgt_microirrigation.html (Consulted the 04/12/2019)

TNAU, 2013. “Greenhouse cultivation” http://agritech.tnau.ac.in/horticulture/horti_Greenhouse%20cultivation.html (consulted the 29/11/19)

VAN DER LINDEN, A.M.A. et al. 2016. « Fate of Plant Protection Products in Soilless Cultivations after Drip Irrigation: Measured vs. Modelled Concentrations” National Institute for Public Health and the Environment: Bilthoven, The Netherlands, pp. 2–61

VAN OS, EA, Gieling ThH, Ruijs MNA. 2002. Equipment for hydroponic installations. In: Hydroponic Production of Vegetables and Ornamentals (Savvas D; Passam H C, eds), pp 103 141. Embryo Publications, Athens, Greece

VOX, G. et al. 2010. “Sustainable greenhouse systems” In Sustainable Agriculture: Technology, Planning and Management; Nova Science Publishers, Inc.: New York, USA; pp. 1–78

WANI. KP, SINGH. PK, AMIN. A, MUSHTAQ. F, DAR. ZA. (2001) “Protected cultivation of tomato, capsicum and cucumber under Kashmir valley conditions” Asian Journal of Science and Technology. 1(4):056-061.

WARREN, S.L. and BILDERBACK, T.E. 2005. “More plant per gallon: Getting more out of your water” Horti-technology, 15, pp. 14–18

YADAV, K. S. 2018 “High-tech Horticulture: Protected Vegetables Production in Subtropics under Changing Climatic Scenario” International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706Volume 7 Number 08

ZENG, C.Z. et al, 2009. “Determination of optimum irrigation water amount for drip-irrigated muskmelon (Cucumis melo L.) in plastic greenhouse” Agricultural Water Management, 96, pp. 595–602

Appendices

Annex 1: Indian farmers questionnaire

Name of the farmer / शेतकऱ्याचे नाव: Age / वय: Qualifications / पात्रता:
Name of the Village/ गावचे नाव: District / जिल्हा:

1. What do you think about modern technology? आपल्याला आधुनिक तंत्रज्ञानाबद्दल काय वाटते?

2. How do you situate your knowledge about farming technology?
शेती तंत्रज्ञानाविषयी आपले ज्ञान कसे ठरवावे?
Inexistent / नसलेला Low / कमी Medium / मध्यम High / उंच
Really high / खरोखर उच्च आहे

3. Would you like to implement modern technology? आपण आधुनिक तंत्रज्ञानाचा अवलंब करू इच्छिता?
Yes / होय No / नाही

4. Why? का?

5. What is the raise of income due to the equipments? मशिनरी वापरल्याने तुमच्या उत्पन्नात काय वाढ झाली …….. रुपये

Circle or stick your own answer. Please do not stick if you do not understand it.
स्वतःचे उत्तर वर्तुळ किंवा टिकमार्क करा. कृपया आपणास हे समजत नसेल तर टिकमार्क करू नका.

Questions/प्रश्न		Disagree असहमत	Agree अंशतः सहमत
1	I maintain my own equipment. मी स्वतःची उपकरणे सांभाळतो.		
2	I have experience with greenhouse, and I can run one. मला ग्रीनहाऊसचा अनुभव आहे आणि मी एकटा चालवू शकतो		
3	I have a good opinion about bank and loan. माझे बँक आणि कर्जाबाबत चांगले मत आहे.		
4	I am ready to invest money to modernize my farm. मी माझी शेती आधुनिक करण्यासाठी पैसा गुंतवणूक करण्यास तय्यार आहे.		
5	I will invest on greenhouse even without subsidies. मी ग्रीनहाऊस मध्ये अनुदानाशिवाय गुंतवणूक करण्यास तयार आहे.		

Thank you very much for filling this form.
आपण हा फॉर्म भरुन दिल्याबद्दल खूप खूप धन्यवाद..

Annex 2: European Marketing Standards for tomato

COMMISSION IMPLEMENTING REGULATION (EU) No 543/2011
of 7 June 2011
laying down detailed rules for the application of
Council Regulation (EC) No 1234/2007 in respect of the fruit and
vegetables and processed fruit and vegetables sectors.
CONSOLIDATED TEXT: Annex I; Part 10 of Part B

Tomatoes are classified in three classes, as defined below:

(i) "Extra" Class

Tomatoes in this class must be of superior quality. They must be firm and characteristic of the variety and/or commercial type.
Their colouring, according to their state of ripeness, must be such as to satisfy the requirements set out in the third paragraph of point A above.
They must be free from greenbacks and other defects, with the exception of very slight superficial defects, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package.

(ii) Class I

Tomatoes in this class must be of good quality. They must be reasonably firm and characteristic of the variety and/or commercial type.
They must be free of cracks and visible greenbacks. The following slight defects, however, may be allowed provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package:

- a slight defect in shape and development,
- slight defects in coloring,
- slight skin defects,
- very slight bruises.

Furthermore, "ribbed" tomatoes may show:

- healed cracks not more than 1 cm long,
- no excessive protuberances,
- small umbilicus, but no suberization,
- suberization of the stigma up to 1 cm^2,
- fine blossom scar in elongated form (like a seam), but not longer than two-thirds of the greatest diameter of the fruit.

(iii) Class II

This class includes tomatoes which do not qualify for inclusion in the higher classes, but satisfy the minimum requirements specified above.
They must be reasonably firm (but may be slightly less firm than in Class I) and must not show unhealed cracks.
The following defects may be allowed provided the tomatoes retain their essential characteristics as regards the quality, the keeping quality and presentation:

- defects in shape and development,
- defects in colouring,
- skin defects or bruises, provided the fruit is not seriously affected,
- healed cracks not more than 3 cm in length for round, ribbed or oblong tomatoes.

Furthermore, "ribbed" tomatoes may show:

- more pronounced protuberances than allowed under Class I, but without being misshapen,
- an umbilicus,
- suberization of the stigma up to 2 cm,
- fine blossom scar in elongated form (like a seam).

Annex 3: Interview of Mr. Sunil Rewar, National Horticultural Board, 20/11/2019

1. **What are the differences in terms of subsidies between low-tech and high-tech polyhouses?**

Subsidies are available for both kind of structure. Indian farmers generally prefer low-tech polyhouses which are less costly, while greenhouses subsidies are more demanded from Research and Development Institutes (Government, ICAR). The subsidies are based on the BIS Standards for construction. Thus, 100% subsidies are often given to greenhouses projects while 50% are allocated for polyhouses. In case of High-tech polyhouse, the standard is around 844Rs/m² including drip irrigation and fogging system.

2. **Which percentage of farmer are investing in polyhouses just because of subsidies?**

Depending on their financial situation, 25 to 30% of farmers are investing in polyhouses because of the subsidy's availability. In case of investment, after approval of the project from NHB, the farmer is bringing 25% of the price and can obtain a term-loan from the bank for the remaining 75%. After construction of the polyhouse and if this one respects the BIS Standards, NHB is repaying 50% of the loan to the bank directly.

3. **What is the average increase of income due to such an investment? What is the average profit with and without polyhouse for the farmers who are approaching NHB?**

In traditional agriculture, the farmers have an average profit of 10 to 50,000Rs per month. After investing into technology (polyhouse), their profit can increase to 50 to 75,000Rs per month. For example, in 4,000m² of polyhouse (1 acre), the gross return would be around 40Lakh Rs/acre, thus around 50,000Rs/month for tomato production.
If two crops are cultivated during the years, for example cucumbers (4 months life cycle), the gross income would be around 6Lakh Rupees per year while in traditional agriculture without polyhouse the farmers' profit are located maximum at 1.5 to 2Lakh per year, highly depending on climatic conditions. Indeed, in case of bad weather conditions, the farmer may not get any return from the open-field production.

4. **As observed during the consultancy from NHB, what is the position of farmers toward modern technology in Maharashtra?**

The state of Maharashtra is one of the most developed state in terms of technology for agriculture. The farmers are demanding more and more financial support to NHB, but also technical support. The open cultivation is increasing with a high demand especially for fruits production (pomegranates, grapes…). Meanwhile the surface and demand for modern protected cultivation is increasing to produce high value vegetables as tomato, capsicum and cucumber (cash crops) but also parsley, celery, broccoli and leafy vegetables. The controlled conditions of production enable a production round the year with good rated in off-season, and the quality of products enable farmers to reach market target as 5 stars hostel and thus better profits.

5. **What are the main constraints in the adoption of technology for farmers?**

At this stage in Maharashtra, the main constraints observed from NHB for the adoption of technology for farmers is first the high investment cost and in the second place the lack of knowledge to produce high quality vegetables in controlled conditions. More and more farmers are applying for trainings at different institutes as KVK, National Horticultural Board or Centre of Excellence. The mission of National Horticultural Board is to promote horticultural development for farmers. Resulting from the high demand, around 40% of the consultancy is offered in Maharashtra. Moreover, organisms and institutes are also helping farmers in the process of getting loans from the bank and are furnishing trainings both on the technical aspects of production and on personal development (entrepreneurship, communication and so on).