Research Article

Hydroponic Tomato Production and Productivity Improvement in Pakistan

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Abstract | Hydroponics production system is state of the art technology, ensuring round the year high quality vegetables free from any residual effects and multiple time productivity in specially developed glasshouses under controlled weather conditions during summer and winter. Rising population and stagnancy both in yield of vegetables and cultivated area of the country, are negatively affecting food supply in Pakistan. Supply of hydroponics products provides solution to the problem of decade old stagnancy in yield of the vegetables especially tomato to cater the increasing demand due to gigantic population increase. This study has been designed to analyze the hydroponics production system and productivity improvement option in Pakistan and its future prospects. Study is based on primary data collected by the researcher. Sample firm was Farmers Market Pvt. Ltd which is unique entity involved in commercial production of hydroponic products in Pakistan. Data on various production and economic variables was collected from FMP during 2009 to 2013. Variable of the study were area, area allocation decisions of farmer, customer structure, markets, costs involved in production process and revenue earned from selling of the produce in both local and in export market. Yield of hydroponic tomatoes was measured in hectares. Benefit cost ratio was studied and other measures of performance like export intensity, local penetration ratio etc. were also analyzed. Average yield of hydroponic tomatoes was found to be 161.8±6.6 ton per hectare as against 10.07±0.4 in open field. The BCR was found positive at 1.07 and 1.44 for with and without casual labor respectively. Analysis suggests that this technology can improve the yield of tomato in the country and solve the demand and supply gap of Pakistan besides helping in export promotion and import substitution. Various factors identified in analysis have been further examined and measures have been suggested to improve supply of tomato in Pakistan.

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Introduction

The geographical area of Pakistan is 79.61 million hectares (m.ha.). Cultivated area of Pakistan is only 22.2 m.ha. (GoP, 2014) from last many decades. The historical trend of cultivated area shows limited scope of horizontal expansion. This poses a constraint to the increase in supply of food in the country. In Pakistan 50 million people are working in agriculture sector and producing 25 million tons of food grains (Hussain and Akram, 2008). Agriculture and food security policy of Pakistan aims at creating modern, efficient and diversified agricultural sector, with more innovation and technology-based agriculture (Ministry of National Food Security and Research, 2012). Pakistan is the country of about

188.02 million people (GoP, 2014), the world sixth biggest populated country (United Nation, 2014). All international agencies have been focusing on this alarming situation of high population growth rate on the basis of their long run projections (Pinstrup et al., 1999; Braun, 2007 and 2008). This increasing population needs more food supply for existence.

During sixties, Pakistan experienced multiple increases in yield of different crops as onset of green revolution in the country. After sixties, late seventies envisaged high agriculture growth as a spillover effect of green revolution. Afterward mixed trend was observed in Pakistan's agriculture (Ghaffar and Mustafa, 1997).

The population increase is still on the up and need another boost in the yield to meet the increasing demand at national level. Horizontal expansion in terms of area is limited but vertical expansion has greater scope as average yield of different crops is lower in Pakistan relative to the world average (Shahnaz et al., 2009).

Technological development can play a significant role along with development in social norms. Productivity and wages are relatively low in agriculture sector as compared to manufacturing sector in the country and elasticity of employment in agriculture sector has drastically declined during last two decades (Irfan, 2008). UN Sustainable Development Goal 2 End hunger, achieve food security and improved nutrition, and promote sustainable agriculture" and 2.2, 2.3, 2a and 2b mainly focused on improving productive capacity and stressed to double agricultural productivity by 2030 in developing countries (UN SDG, 2016). Draft Agriculture Policy of Pakistan 2013, also focused on new technology for enhancing productivity in the country (GoP, 2013).

Vegetables are the main item of diet in Pakistan and almost every household use some vegetable every day as food because they are cheaper source of energy (Alertor et al., 2002; Hussain et al., 2009). Per capita consumption of vegetable during 1960 was 10.6 grams per day (Khan, 1969). Pakistan is among the low vegetable consumption prevalence countries where vegetable consumption prevalence was estimated as 99.2% in men and 99.3% in women (Hall et al., 2009). While per capita consumption of vegetable in Turkey and Brazil were 242 kg per annum. Per capita supply of vegetables in Pakistan is lowest as compared to its neighboring countries. The per capita per annum consumption of vegetables as per FAOSTAT Food Balance Sheet database was 26.34, 88.71, 46.24, 28.97, 114.09 and 27.34 kg in Pakistan, India, Sri Lanka, Afghanistan, Nepal and Bangladesh respectively. The expenditure on food was mainly determined by socio-economic factors in Pakistan (Habib et al., 2015). They also provide important biochemical and nutrients like carotene, protein, carbohydrates, vitamins, iron, calcium etc. (Salunkhe and Kadam, 1995). Vegetables can play very important role in combating hunger and malnutrition (Rensburg et al., 2004). Vegetable provide resistance against cancer (Van Poppel et al., 1999). Vegetables are an important component of human diet all over the world, thus their supply needs to be regulated for better health of the community. Keeping in view the importance of vegetable in the national economy, study in hand has been planned with the objective to analyse performance of hydroponics sector in vegetable productivity and assessing its cost and benefits under local conditions in Pakistan. After introduction, next section describes hydroponics technology in the globe and Pakistan so that reader can understand the technology easily. Methodology of the paper is given after description of hydroponics technology which is followed by results and discussion and conclusion.

Hydroponics vegetable production

Worldwide development in hydroponic production: Hydroponics is a process of growing plants in water, word hydroponics is differently defined in various dictionaries like in oxford dictionary, "The process of growing plants in sand, gravel, or liquid, with added nutrients but without soil". In Dictionary.com "the cultivation of plants by placing the roots in liquid nutrient solutions rather than in soil; soilless growth of plants" and in Wikipedia, "Hydroponics is a subset of hydroculture and is a method of growing plants using mineral nutrient solutions, in water, without soil". According to United State Department of Agriculture, "hydroponics is a process of growing plants in nutrient solution culture (Syrocki, 1961), this solution provides nutrients to the plants for normal growth of the plant.

Hydroponics is a successful and rapidly expanding industry in the world over (Carruthus, 2002) and is developed manifold in developed countries like four to five folds in last decade in Australia (Hassall and Associates Pvt. Ltd. 2001). Hydroponic technology

is a capital-intensive technology involving development of infrastructure which has positive impact on productivity and growth (Imran, 2011). US department of labor classify food crops grown under cover as 0182 sub-head of major Agriculture production as 01 (USDL, 2014).

Farmers Market Pvt. Ltd. (FMP), a company registered in Pakistan with Security and Exchange Commission of Pakistan (SECP) under company's ordinance 1984 during 2003, is the main body in this study. The company is incorporated for production of horticultural crops in high tech. system with independent Board of Directors and management staff. In March 2009, company has been transferred to Pir Mehr Ali Shah Arid Agriculture University Rawalpindi (PMAS-AAUR) on the basis of board resolution. This company is pioneered in production of hydroponics horticultural crops in the country.

Economical production of hydroponics tomato improves the productivity and farmers profitability. Benefit cost ratio of tomato production under drip irrigation in net houses was found to be 5.19 with the application of farm yard manure. Payback period of investment in net houses using drip irrigation was calculated as one and half years (Dunage, 2010).

Area allocation under hydroponics at FMP

Crop production data collected for, this study started from July 2009. Various crops produced at FMP were tomato on vine, cherry tomato, bell pepper and other mixed vegetables. Total area of the facility was 20,000 sq. meter. Area distribution under each crop during specific year was given in Table 1, which indicates the weightage (demand) of the crop.

Table 1: *Area allocation under hydroponics production for different crops at FMP.*

Year/ crop	Total Area (sq.m.)	Tomato on vine %	Cherry tomato%	Bell pepper%	Others%
2009-10	20000	85	10	3	3
2010-11	20000	75	15	10	0
2011-12	20000	45	18	38	0
2012-13	20000	60	18	18	5

Market structure

Marketing is the process of selling goods in local and international market. FMP was involved in selling its products in local and export market. In local market cost was incurred on transportation and promotion activities while in export market, CNF price was offered to the client. The freight from Pakistan to Middle Eastern countries revolves around 1US$. The high market cost was mainly due to this reason.

Table 2: *Major export partners of FMP.*

Country	Cities	Stores
Kingdom of Saudi Arabia	Riyadh Dammam	Lulu Hypermarket, Shahzad Zafar Trading Est., Saudi Hypermarkets
United Arab Emirates	Dubai	Delmonte, Grand Castle Trading Establishment, Unifruti Middle East, Pan Fresh International, The Fresh Corner
Qatar	Doha	IBN Thamer
Bahrain	Bahrain	Shahzad Zafar Trading
United Kingdom	London	Amer Super Fresh, Spital Field Market London

Source: *Authors' compilation based on FMP data.*

Customer value proposition of FMP products

Customer value proposition is the preference of the product from its competitors in the market (Kotler, 2015). The major characteristics which dignify FMP tomato on vine from local tomatoes were, shining, nutrients enriched, beautiful, low sodium contents, less perishability, sweetness (best for salad), packing and homogeneity in size and color.

Similarly, sweet bell pepper of FMP has different characteristics like sweetness, different colors like red yellow and orange, beauty, packing, equal size and more solid contents etc.

Export markets for hydroponics products of Pakistan Middle East (ME) and Europe is the potential markets for hydroponics products of Pakistan. These markets are buyer driven and retailers play key role (Dolan, 1996). FMP was producing high quality products on international standards. Major export products include Tomato on vine and Cherry tomato. Production of Bell pepper hardly matches local demand. The products were certified on ISO-9001:2008, ISO 22000: 2010 and Global GAP standards. These products have a very good market in the Middle Eastern countries and Europe. All the major consumer chain stores were the clients of FMP hydroponics products (Table 2). The major limiting factors in marketing were observed as scale of production and shortage of supply. By up-scaling the green houses, all these potential clients demand can be tapped.

Materials and Methods

Selection of hydroponic firm

Hydroponics is a capital intensive modern technology and is tested in Pakistan by a company known as Farmers Market Pvt. Ltd. (FMP). FMP used this technology to produce high quality vegetables to cover the niche market of Middle East and the sub-continent. The company was unique in its nature in South Asia in hydroponic sector.

The production facility of the company was located at Rawat, Islamabad and partly in Kalyam Awan, Gujar Khan tehsil of Rawalpindi on both sides of GT Road joining Rawalpindi to Lahore. GPS location of the hydroponics plant is 33.424054 N and 73.223550 E.

This study is based on primary data collected from FMP. FMP is the only commercial hydroponic entity in Pakistan. FMP was selected as only option for sample analysis. Data was collected from FMP on monthly basis from 2009-2013. First crop was sown in July 2009 and four successive crops had been sown every year and the data on all economic and production parameters were collected which provided the main body of data for present study. The company developed its own system of inputs purchase and inventory management, crop production, sale of crop and its marketing and export. The company was actively involved in production, processing and marketing of its products both local and abroad. The data was maintained on daily basis and appropriate registers were maintained. Daily data was then organized on monthly basis. Scheme of data collected on different variables include Input and Output data.

Input data include all the inputs involved in hydroponics production process and on which some expenditure has been incurred for financial analysis. Inputs can be divided into Fixed and variable inputs. Fixed inputs include expenditure incurred on land, building, Green house machinery, computer and relation equipment's, Electrical equipment's, furniture, fixture and equipment's, office equipment's, vehicles and other physical assets. Variable inputs include labor, energy (WAPDA electricity bills, diesel for generators during load shedding hours and Liquefied Petroleum Gas LPG used during 2009-10), input supplies (chemicals, growing supplies, Rockwool, coco peat slabs, etc.), marketing cost (expenditure incurred on transportation of product, freight for product export, advertising and exhibition etc.), administrative cost, cost on capital goods purchased during the year and miscellaneous expenses.

Output data include production data of each crop and sale record of different crops. The data include quantity of product sold to each client and prices of each product. Prices of each product were notified by the company depending upon market situation, season and prices of substitute. Price fluctuation was envisaged in case of tomato on vine due to availability of substitute. Bell pepper and cherry tomato prices were remain fixed during whole year due to poor competition in the market.

Data

Data of four years from 2009-10 to 2012-13 was collected on different parameters of hydroponic farm in Pakistan namely Farmers Market Pvt. Ltd. The data set was comprised of monthly and yearly data starting from 2009 till 2013. Monthly disaggregated Data of Farmers Market Pvt. Ltd was also collected from 2009 to 2013. Secondary data required for analyzing different parameters was also collected from different sources like Economic Survey of Pakistan, Agriculture statistics various editions, Pakistan Federal Bureau of Statistics and FAOSTAT etc.

Yield, seasonality and export orientation in hydroponics

Measurement of yield of hydroponics production system: Yield of each crop was obtained by dividing production of crop in specific area divided by area in which said crop is sown (Equation 1).

$$Y_i = {}^{Pi}/_{Ai} \qquad (1)$$

Where; Yi: Yield of respective crop like tomato on vine, cherry tomato and bell pepper; Pi: Production of respective crop in specific area. Ai is the total area allocated to each crop.

Seasonality in production and sales of hydroponics: Crop production behavior includes three to four months from sowing till start of harvesting depending upon nature of crops. At FMP, this gestation period for tomato on vine was observed to be three months, for cherry tomato two and a half month and for bell pepper three and a half month. Crops remain in production for remaining nine months of the year. Due to limitation of resources especially energy resources, effect of weather was also observed on production.

During extreme weathers production affected adversely causing decrease in supply of product.

Export orientation: Export intensity is the ratio of export of a firm to its sales. Export intensity is the common measure of export performance of a firm or country (Reis and Forte, 2014). Total factor productivity of a firm is negatively correlated with export intensity to low income destinations and positively correlated to high income destinations (Carino and Apifani, 2009). Determinants of export intensity of a firm are labour productivity and size of firm (Reis and Forte, 2014). Export intensity was calculated by dividing export sales of the firm by total sales of the firm in the specific period (Equation 2) following (Soloman, 2005).

$$Export\ Intensity = \frac{Export\ Sale}{Total\ Sale}$$

Cost benefit analysis

Costs in hydroponics production system: Cost of production of off season vegetables vary from crop to crop. Cost of production of tomato is higher than other off-season crops (Bala et al., 2011). In hydroponics production system, cost of production is higher even from off season vegetables production system due to its industrialized nature and need equipment and machinery for running every operation and further automation of the system. Cost of production of FMP hydroponics production system can be divided into two major categories: Fixed Cost and Variable cost.

The components of fixed cost of a hydroponics firm are the cost incurred on land, building, green house machinery, monitoring computer and related equipment, electrical and mechanical equipment, furniture fixture, vehicles and other related materials.

Land is the basic factor of production, for ten acres of green houses, one acre is required for related machinery and equipment and other services. So, ratio of (1.0: 0.1) is required between production area and machinery equipment. The higher cost of FMP on land was due to the use of machinery and equipment excessive to the optimally required magnitude.

BCR: BCR was calculated by dividing Gross benefits with total cost (Equation 4)

$$BCR=B/C \quad (4)$$

SWORT analysis

For improving the corporate strategy of the industry, SWOT analysis is considered to be the strong tool (Hill and Westbrook, 1997). Knowing internal strengths, external weaknesses, better opportunities and internal and external threats is important for better performance of a firm (Houban et. al. 1999). SWOT analysis can be used in relation to some other models for improving its efficiency in decision making (Kurtilla et al., 2000). The analysis was based on Bontji Model (Bontji, 1988) which includes Market of output and input, Capital/ financial requirements of the project, Production process and its further consideration, ultimate consumers of the product and their behavior and lastly the environment and environmental factors. These factors guide in SWORT analysis of the hydroponics production firm.

Results and Discussion

Yield, seasonality and export orientation

Green house production technology is changing yield of different crops so rapidly than before (Jenson, 1999). Average yield of tomato in Pakistan was observed to be around 10 ton/ha (Figure 1). The yield of tomato from last three to four decades is stagnant. Better yield can be obtained by improving management practices. In research experiments, maximum yield of tomato was obtained 41.45 ton/ha in Pakistan (Hussain et al., 2001).

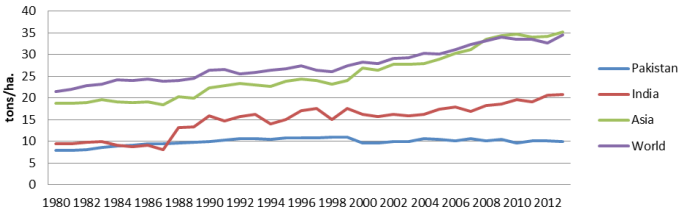

Figure 1: *Comparasion of global tomato productivity.*

In hydroponics average yield of tomato was obtained 161.8± 06.6 tones /ha in Pakistan as compared to field tomato average production of 10.07±0.4 ton /ha. during four-year period (2009-13). The average yield of India, Asia and World was 19.47± 0.83, 34.28±0.27 and 33.37±0.57 respectively during period under study. This yield stagnancy is forcing Pakistan to import tomato of worth Rs. 9.2 billion during 2011-12 (GoP, 2013).

Seasonality

Four years monthly data of hydroponic firm (FMP)

has been analyzed to understand the seasonality in sale revenue of the firm. The month of September and October are the lowest sale months of hydroponic firm. This also reflects the production pattern because during these months the production of tomato stops due to old crop replacement.

Monthly Sale behavior of FMP was shown in Figure 2. The fluctuations depict the crop production behavior. The months with minimum value depict the crop end stage and new crop sowing stage. During initial year the minimum value touches zero as all crop ends. In the later years Alternate crop policy was used. This was successful policy and provides revenue during these days/ months.

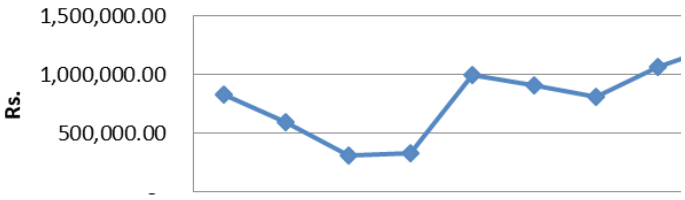

Figure 2: *Seasonality in sale revenue of hypdoponic firm.*

Pricing mechanism of hydroponics products in local and export market

Price variability in perishable commodities is the major problem in global market. World Food Price Index has been decreasing with the passage of time from 210 in May 2014 to 154.1 in Dec. 2014 based on 2002-04 prices. Major destination of FMP products was UAE, Qatar, KSA and Bahrain. Prices in UAE market face more global competition as compared to other destination due to volume of the market. All the clients (100%) demanded CNF prices of CIF prices. For producer, FoB prices were more preferable. The prices fetched by hydroponically produced Tomato on vine of FMP in each year were given in Table 4.

The products of FMP were of high quality and produced under strict food safety standards ultimately increasing cost of production. The market competitiveness behavior of FMP products was different in different markets depending upon substitution and income effect. In niche markets, this product has no close substitute resulting in fetching high price above the cost of production. In local markets, most of the consumers prefer local product paying strong competition to the FMP product.

FMP was producing tomato on vine, bell pepper and cherry tomato under hydroponics system. Average annual production of tomato on vine under hydroponics was recorded as 161±7 ton per ha. as compared to 10 ton per ha in open field as reported by GoP, 2013. Under research trials of hydroponics maximum and minimum yield estimated was 245.3 and 138.3 ton per ha. in India (Joseph et al., 2014). Maximum yield of cherry tomato recorded was 57±26 t/ha. Average yield of cherry tomato was recorded as 47±7 (SD) ton per hectare.

Export orientation

Terminal wholesale market near the production facility of hydroponics was Islamabad Fruits and vegetable market. Terminal market provides assembling and selling points for producers and wholesalers and retailers (FAO, 2004). FMP was selling its high-quality products in the local niche markets along with exporting major share of production to international destination. Initially the products had slow response in the local market. The local sales during first year were Rs. 0.63million during 2009-10. The same volume of local sale doubled in 2012-13 i.e., Rs.1.29 million

Local sale showed upward trend in the previous four years and increased more than doubled in four-year period indicating acceptability of the product in the local market. Exports showed mixed trend due to competition with local and surrounding regional produce in the international market. Consumption of hydroponics products depends mainly on income, preferences of consumer and market prices (Rual, 2005) (Figure 3).

Cost benefit analysis

Major cost in investment in hydroponics was on structure of greenhouses which is 80 percent of the total cost. These structures have several advantages and disadvantages. These are suitable under different conditions. Their cost varies from Rs. 0.02 million per acre to as high as Rs. 20 million per hectare. Land cost is just 10% of the total cost (Table 6). Generally, most of the interested people belongs to farming community and may own some piece of land. A farmer having own land can save this cost in terms of capital cost.

Furthermore, a simple local made hydroponic structure with efficient cooling system (Pad-wall System) and local heating system can be prepared with a cost of Rs. 40 million per ha. Few elements of the machinery and equipment were not required in Pakistan

climate and even many of them can be reduced if installed in climatically favorable zones like moderate zones of coastal areas of Sindh and Baluchistan, Abbottabad, Potohar and few areas of KPK province of Pakistan. Computer and related items were required for controlling daily operations of the glass houses and maintenance of comfortable system for crop for avoiding human error. Electrical and related equipment are required for maintaining regular electricity supply for electrical equipment. A shut down of electricity for 2-3 hours during peak summer season is enough for damaging the crop. Vehicles include greenhouse carts and marketing vehicles. One cart is enough for one acre of green house. This rationalization decreased capital cost to Rs. 32.50m. Instead of Rs. 428 m. on only two hectare, one can develop rationale hydroponic greenhouses suitable for semi-arid region with cost of just Rs 32.50 million on same area. In this study Rs. 16.25 million per hectare was used as fixed cost for further analysis with an average life of twenty years, thus incurring annual fixed cost of Rs. 0.812 million annual depreciation (Table 9).

Labor and energy cost can further be decreased by improving efficiency of the system through indigenization. Marketing cost mainly include freight on export. By increasing share of local sale in export, this cost can also be decreased significantly.

Revenue estimation

If the customers are blood of any firm in a business model, then revenue generation is the arteries. Revenue plays an important role in the development of successful business model. Maximum revenue earned by FMP was Rs. 41.8 m/2 ha in 2011-12 (Table 8).

The ratio of local sale to export would guide us the development process of local market of FMP products in the country. The ratio indicates that the local market for hydroponics products of FMP was developing rapidly with an annual growth rate of 29%. This rapid development of local market is a clear indicator of future prospects of hydroponics technology in the country. During initial years the ratio of local sale to export was very high, i.e., during 2009-10, local sale to export ratio was 1: 4.88 (Table 3). Gradually the local market developed and this ratio decline to 1:1.42 in 2012-13. Factors contributed in development of local market were introduction of new products, price stabilization policy in one big market of Rawalpindi /Islamabad, flexible prices on low grade product, price negotiations with chain stores, massive marketing campaign through exhibitions and seminars and opening new markets and customers.

Table 3: *Comparison of Tomato Yield Hydroponics with open field Pakistan India and world.*

Year	Commercial Hydroponic	Open Field			
	Pakistan	Pakistan	Indian	Asia	World (ave)
2009-10	168.4	10.524	18.6092	34.353	33.939
2010-11	158.3	9.538	19.5984	34.601	33.475
2011-12	154.3	10.137	19.1052	33.942	33.501
2012-13	166.3	10.099	20.5656	34.236	32.566
Average Yield	161.8± 06.6	10.07±0.4	19.47± 0.83	34.28± 0.27	33.37±0.57

Pakistan is generally facing serious trade deficit from decades despite adopting all measures of export promotion (Badar, 2006). The export intensity of FMP hydroponics project was very high in the initial years (0.83 in 2009) and gradually decreased during subsequent years and reached to 0.63 during 2012-13 (Table 4) but still is on higher side (above 0.5) indicating FMP as export-oriented firm. The value of export intensity also indicated that FMP and or hydroponics production system has more global acceptance and has more potential of export in the agriculture sector. Declining trend of export intensity was firstly due to increasing acceptance of FMP products in the local markets and gradual development of taste in the country as envisaged from increasing trend of local sales of hydroponics products (Table 5). Enhanced competition in the export market might be the other factor contributing to the decreasing trend of export sales.

Table 4: *Pattern of Total Revenue Generation by 2 ha FMP Hydroponics Farm 2009-13.*

Year	Average Price (Rs per Kg)	Total Revenue (Rs)
2009-10	130	37,075,983
2010-11	168	34,957,108
2011-12	345	41,864,884
2012-13	255	35,215,857

Gross margins and net farm income

Net Farm Income of FMP was found by deducting fixed cost from gross margins. It supports farmer in understanding return from labor, management and capital (Wikipedia, 2015). Net farm income provides

better understanding of the wellbeing of farming sector in relation to input output and marketing conditions during a year (Schneph, 2010).

Economies of scale and more specialization in the technology through indigenization can further reduce the operational cost and may result in doubling the BCR. Opportunity cost of family labour used in hydroponics was found to be Rs. 4.575million per ha. per annum (Table 7). The opportunity cost of labour was calculated by taking average labor cost on the basis of four years of hydroponic operation.

Figure 3: *Sale Pattern and Sale Ratio of FMP Hydroponics Products.*

Table 5: *Export intensity of FMP 2009-13.*

Year	Export Intensity	Local Penetration Ratio
2009-10	0.83	0.17
2010-11	0.75	0.25
2011-12	0.69	0.31
2012-13	0.63	0.37
Average	0.72	0.28

Table 6: *Distribution pattern of fixed cost of a hydroponic firm (FMP).*

Cost Item	Share
Land	10.02
Building	6.48
Green House Machinery	80.17
Computer & Related Equipment	1.02
Electrical Equipment	0.09
Furniture, Fixture & Equipment	0.54
Office Equipment	0.23
Vehicles	0.98
Other Assets	0.47

SWORT analysis of hydroponics firm

Strengths: a): Hydroponics can be characterized as high productivity production system as compared to open field (tomato production achieved was 168 ton per ha. even compromising 30% of winter production due to non-availability of natural gas); b): It provides best quality highly nutritious products for local and niche markets with sweet taste; c): Diversity in production of many kinds of local and exotic vegetables; d): Hydroponics products are safe for human being as they are free from all kind of pesticide spray; e): Local labor is now trained in hydroponics; f): Technology has been tested under local conditions; g): Pakistan can lead the SAARC region in hydroponics technology as the commercial unit of hydroponics vegetable production is only tested in Pakistan in the SAARC region.

Weaknesses: a): It is capital intensive (fixed cost is high) technology due to both high fixed and operational cost; b): Load shedding of electricity and gas create operational hurdles; c): High humidity in monsoon cause problem for pollination of tomatoes, ultimately decreasing productivity; d): Severe weather condition during extreme summer and winter may cause decrease in productivity; e): Export by air is costly (minimum by air freight charges were US 1 $ per Kg).

Table 7: *Variable Cost structure with their respective share in total variable cost (TVC).*

Cost items	Description	Ave Cost	% share
Labour cost	Skilled and unskilled	4,539,436	22
Energy	Electricity, LPG, diesel for backup Genset	3,187,794	15
Inputs	Chemicals for recipe and growing supplies	2,971,616	14
Marketing	Sales Promotion, exhibition, logistics and transportation	6,694,607	32
Miscellaneous		52,048	0.24
Capital	Fixed items	3,569,443	17

Opportunities: a): Fixed cost of FMP as reported in its annual audit report was Rs. 418.70 million as on 1st July 2007 (FMP, 2010). The basic investment on green houses and other machinery and equipment's used to run the system was Rs. 245million for two ha green houses. This cost was still on higher side as everything used in erection of these green houses were imported from Holland, ultimately increasing the extra cost burden on the project. Now a day's majority of the items were available at cheaper price in domestic

Table 8: *Production and Revenue Generation of different vegetables at FMP (2009-13).*

Year	Sales Markets	Tomato	Bell Pepper	Cherry Tomato	Cucumber	salad Pack	Other	Total Revenue (PKR)
2009-10	Export sales	237,085		32	100	333		30,768,265
	Local sales	49,276	8,492	2,669	10,733	14,913	815	6,307,718
	Production	286,361	8,492	2,701	10,833	15,246	815	37,075,983
2010-11	Export sales	156,672						26,268,021
	Local sales	80,797	12,143	4,601				8,689,087
	Production	237,469	12,143	4,601	-	-	-	34,957,108
2011-12	Export sales	83,761		58,998				28,865,976
	Local sales	55,129	19,126	5,478		206		12,998,908
	Production	138,890	19,126	64,476	-	206	-	41,864,884
2012-13	Export sales	80,979		15,038				20,670,085
	Local sales	118,635	17,525	7,757	4,906	453	427	14,545,772
	Production	199,614	17,525	22,795	4,906	453	427	35,215,857

Source: *Authors own calculations.*

market of Pakistan; b): The structure of machinery and equipment was western based, where cold weather is dominant feature, resulting in requirement of efficient heating system. In contrast, eastern environment is relatively more towards hot weather which need better cooling system; c): Pakistan's Weather is relatively more favorable for this technology as compared to globe; d): High market price of the hydroponics products in local and export markets; e): Export market is vast (in summer Middle East is net importer and in winter UK/part of EU is net importer); f): By ship export may revolutionize the industry as profit increase many fold (CPEC opportunity). Maximum sea freight is US 0.2$ per kg as compared to air freight of more than 1US$. By sea transportation is possible through refrigerated containers; g):Water purification cost through reverse osmosis can be eliminated and water can be saved by installing the units on most of the small dams in Potohar and other suitable regions depending upon EC and pH of rain water; h): Commercial import of salts can reduce unit cost (CPEC opportunity); i): Improvement in health of the consumers through diseased and pesticide free products.

Resources: a): Abundant land (utilization of marginal land, out of 79.61 million ha. only 22 is cultivated); b): Skilled and unskilled labor supply for local and international market. (Presently the trained manpower of this project has been engaged by KSA; c): Rainfall water stored in small dams is best for hydroponics production; d): Few inputs are abundantly available in the country like Apsom Salt; e): Sea port is one day travel from Potohar region of Pakistan where the technology is tested; f): Technology testing in other regions with favourable temperature; g): Major salt used in hydroponics is Calcium Nitrate which can be produced locally.

Table 9: *Calculation of Net Farm Income (Rs./ha.).*

	with hired labour	with family labour
Variable cost Rs. /ha	17,445,500	12,906,064
Fixed cost (Rs./ha/annum)	812,500	812,500
Total cost (Rs./ha/annum)	18,258,000	13,718,564
Average Revenue (Rs./ha) of FMP	18,600,000	18,600,000
Gross Margins (Rs./ha/annum)	1,154,500	5,693,936
Net farm Income (Rs./ha/annum)	342,000	4,881,436
Benefit cost ratio (BCR)	1.07	1.44

Threats: a): Most of the Salts used in hydroponics are still imported in Pakistan; b): Taste issue (hydroponics products are mostly used uncooked as table products in the shape of Salad); c): Load shedding of electricity and natural gas can adversely affect productivity.

Conclusions and Recommendations

Hydroponics technology is the technology of the future and Pakistan is forced to adopt this technology based on continuous warnings from World Bank on severe food situation in future because of rapidly increasing population. The yield of tomato is stagnant over last five decades. Cultivated area in Pakistan is also limited. Population of the country is rising. Option for the country is to increase productivity. Conventional methods failed to increase productivity in the past. Adoption of modern technology is the only

option for Pakistan to increase productivity of vegetables especially tomato. Hydroponic technology has been tested in Pakistan and the technology has been proved to be successful in increasing productivity. Average yield obtained in hydroponics in Pakistan is 168 tons per hectare as compared to national average of ten tons per hectare. This technology can increase productivity of vegetables in the country and revolutionize the horticultural sector. The technology has many benefits for the farmers at micro level and for the country at macro level. At micro level, farmers income will increase multiple times and the horticulture sector become high tech. and capital intensive. At macro level, imports of the country will be converted to exports. Foreign reserves will improve. Supply of vegetable will increase in domestic market and increase in per capita consumption will improve health of the consumers.

Future Research Areas

This technology may be tested near routes of CPEC for provision of fresh food in difficult areas of Baluchistan and Makran coasts as specific crops calamities easily in these areas with the help of hydroponics technology ultimately reducing cost of production and investment.

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Author's Contribution

Arshad Mahmood Malik conceived the idea, collected and analysed the data, reviewed the literature and wrote the manuscript. Khalid Mahmood Mughal, Sarfraz Ahmed Mian and Atta Ullah Khan provided technical support at every step. Khalid Mahmood Mughal managed the article overall. Sarfraz Ahmed Mian helped in writing the discussion in the article.

Reference

Akbar, M. and Z.F. Naqvi. 2001. External Market Conditions, Competitiveness, Diversification and Pakistan's Export Performance. Pak. Dev. Rev. 40(4): 871–884.

Alertor, O., A.A. Oshodi and K. Ipinmoroti. 2002. Chemical composition of common leafy vegetables and functional properties of their leaf protein concentrates. Food Chem. 78(1): 63-68. https://doi.org/10.1016/S0308-8146(01)00376-4

Bader S., 2006. Determining import intensity of exports for pakistan, state bank of pakistan, research bulletin. 2(2).

Bala, B., Sharma, N., & Sharma, R. K. 2011. Cost and Return Structure for the Promising Enterprise of Off-Season Vegetables in Himachal Pradesh. Agricultural Economics Research Review, 24(1).

Bontje, J.C.B. and Ondernemersboek. 1988. Doe-het-zelf methode voor Doorlichten en plannen maken in kleine en middelgrote ondernemingen, CED Samson, Brussel.

Braun, J.V. 2008. Rising food prices, what should be done? Int. Food Policy Res. Instt. (IFPRI) Policy Brief, Washington, D.C.

Braun, J.V. 2007. The world food situation: New driving forces and required actions. Int'l Food Policy Res. Instt. (IFPRI's) Bi-Annual Overview of the World Food Situation presented to the CGIAR Annual General Meeting, Beijing.

Crinò, R. and P. Epifani. 2008. Productivity and export intensity to high-income and low-income countries. mimeno Università Bocconi.

Carruthers, 2002. Hydroponics as an agricultural production system. Issue 63: March/April –2002, Story Title: Hydroponics as an agric. Prod. Syst.

Croucher, M. 2013. UAE weather: Temperature soars to near record level, The National UAE. http://www.thenational.ae/news/uae-news/uae-weather-temperature-soars-to-near-record-level

Dolan, C., J. Hamphery and H.P. Carla. 1996. Horticultural Commodity Chains: the impact of UK market on the African fresh vegetable industry, IDS working paper 96.

Dunage, V.S., P. Balakrishnan and M.G. Patil. 2010. Water use efficiency and economics of tomato using drip irrigation under netthouse conditions. Karnataka J. Agric. Sci. 22(1).

FAO. 2004. Manual for the preparation and sale of fruits and vegetables From field to market, by Andrés F. López Camelo, Ph.D. Instituto Nacional de Tecnología Agropecuaria Estación Experimental Agropecuaria Balcarce Balcarce, Argentina. FAO Agricultural Services Bulle-

tin 151 Food and Agriculture Organization of the United Nations Rome, 2004 ISBN 92-5-104991-2. ISSN 1010-1365. http://www.fao.org/docrep/008/y4893e/y4893e00.htm#Contents

FMP. 2010, Annual Audit Report 2010-11, Farmers Market Pvt. Ltd. PMAS-Arid Agric. Univ. Rawalpindi.

Food and Agriculture Organization Statistics (FAOSTAT). 2014. Food and Agriculture Organization of UN statistics. http://faostat3.fao.org/download/Q/QC/E

Ghaffar, C.M. and C.G. Mustafa 1997. Pakistan's Agricultural Development since Independence: Intertemporal Trends and Explanations. Pak. Dev. Rev. 36: 4 Part II (Winter 1997) pp. 593—612.

Government of Pakistan 2013. Fruits, Vegetables and condiments Statistics of Pakistan 2011-12. Minist. National Food Secur. Res. April 2013.

Government of Pakistan 2014. Agriculture Statistics of Pakistan 2012-13. Minist. Food Secur. Res. GoP.

Government of Pakistan a 2014. Trade and Payments. Pakistan Economic Survey 2013-14. Page 127-130, Finance Division, GoP.

Government of Pakistan b 2014. Pakistan Economic Survey 2013-14. Finance Division, GoP.

Government of Pakistan c 2014. Monthly bulletin of FBS August 2014. PBS-22(08/2014) vol.62/100, Statistical division, Pakistan Bureau of Statistics, GoP.

Habib, H.S., A.M. Malik, A. Ali and M.A. Khan 2015. Socio-economics determinants of rural household food expenditure in Rawalpindi, Pakistan J. Agric. Res. Vol.29 No.1, 2016, pp:68-75.

Hall, J.N., S. Moore, S.B. Harper and J.W. Lynch. 2009. Global variability in fruit and vegetable consumption Am J. Prev. Med. 2009 May;36(5): 402-409.e5. https://doi.org/10.1016/j.amepre.2009.01.029

Hassall and Associates Pvt. Ltd. 2001. Hydroponics as an Agricultural Production System. A report for the Rural Industries Res. Dev. Corporation November 2001, RIRDC Publication No 01/141, RIRDC Project No HAS-9A.

Hill, T. and R. Westbrook. 1997. SWOT analysis: It's time for a product recall, Long Range Planning, Volume 30, Issue 1, February 1997, Pages 46–52. https://doi.org/10.1016/S0024-6301(96)00095-7

Hochmuth, G.J. 2015. Production of Greenhouse Tomatoes-Florida Greenhouse Vegetable Production Handbook, Vol. 3, HS788, series of the Hortic. Sci. Depart. UF/IFAS Extension.

Houben, G., K. Lenie and K. Vanhoof. 1999. A knowledge-based SWOT-analysis system as an instrument for strategic planning in small and medium sized enterprises Decision Support Systems 26 _1999. 125–135. www.elsevier.comrlocaterorms

Hussain, S.I., K.M. Khokhar, T. Mahmood, M.H. Laghari and M.M. Mahmud 2001. Yield Potential of Some Exotic and Local Tomato Cultivars Grown for Summer Production, Pak. J. Biol. Sci. 4 (10): 1215-1216. https://doi.org/10.3923/pjbs.2001.1215.1216

Hussain, Z., and Akram, W. 2008. Persistent food insecurity from policy failures in Pakistan. The Pakistan development review. 817-834.

Hussain, J., A.L. Khan, N. Rehman, Z. Ullah, S.T. Hussain, F. Khan and Z.K. Shinwari. 2009. Proximate and nutrient analysis of selected medicinal plant species of Pakistan. Pakistan J. Nut., 8(1): 620-624.

Imran, M. and J. Niazi. 2011. Infrastructure and Growth. Pak. Dev. Rev. 50:4 p355–364 (2011).

Irfan, M. 2008. Pakistan's wage structure during 1990/91-2006/07. Pakistan Institute of Development Economics, Quaid-e-Azam University Campus, Islamabad, Pakistan Dec 2008 report.

Jensen, M. H. 1999. Green house Hydroponics industry status report, Hydroponics worldwide. Acta Hort. 481:719-729.

Joseph, A. and Mathuchamy 2014. Productivity, Quality and Economics of Tomato (Lycopersicon esculentum Mill.) Cultivation in Aggregate Hydroponics - A Case Study from Coimbatore Region of Tamil Nadu, India. J. Sci. Technol. 7.8. (Aug 2014): 1078-1086.

Khan, M.I. 1969. Aggregate analysis of food consumption in Pakistan. Notes and Comments PIDE. www.pide.org.pk/pdf/PDR/1969/Volume4/426-441.pdf

Kurttila, M., M. Pesonen, J. Kangas and M. Kajanus. 2000. Utilizing the analytic hierarchy process _ AHP. in SWOTanalysis - a hybrid method and its application to a forest-certification caseq Forest Policy and Economics 1 _2000. 41-52.

Ministry of National Food Security and Research 2012. Draft Agriculture and Food Security pol-

icy of Pakistan. Minist. National Food Secur. Res. GoP.

Pinstrup, P.A., R.P. Lorch and M.W. Rosegrant. 1999. World food prospects: Critical issues for the early Twenty First Century. 2020 Vision Food Policy Report. Int. Food Policy Res. Instt. Washington, D.C.

Poppel, V.G., D.T. Verhoeven, H. Verhagen and R.A. Goldbohm. 1999. Brassica vegetables and cancer prevention. In Adv. Nutr. Cancer. 2: pp. 159-168. Springer US.

Reis, J. and Forte, R. 2014. The impact of industry characteristics on firmsâ•Ž export intensity. [online] p.1. Available at: http://wps.fep.up.pt/wps/wp524.pdf

Rensburg, W.S., J. van, S.L. Venter, T.R. Netshiluvhi, E.V.D. Heever, H.J. Vorster and J.A. Ronde. 2004. Role of indigenous leafy vegetables in combating hunger and malnutrition, S. Afr. J. Bot. 2004, 70(1): 52–59, ARC–Roodeplaat, Private Bag X293, Pretoria 0001, South Africa.

Ruel, T.M., N. Minot and S. Lisa. 2005. Patterns and Determinant of fruits and vegetables consumption in Sub Saharan Africa. Back ground paper submitted for joint FAO/ WHO conference 1-3 September 2004 Workshop on Fruits and vegetables for Health, Kobe, Japan. http://www.who.int/dietphysicalactivity/publications/f%26v_africa_economics.pdf

Salunkhe, D.K. and S.S. Kadam. 1995. Handbook of fruit Science and Technology: Production Composition, Storage and Processing, Marcel Dakker, New York, 156.

Schnepf, R. 2010. US Farm Income, Congressional Res. Service 7-5700. www.crs.gov R40152

Shahnaz, A.A., A.F. Chishti, M. Zulfiqar, G. Yasmeen, N. Farid and A. Iftikhar. 2009. Estimating Yield Potential of the Major Crops and its Implications for Pakistan's Crops Sector. Sarhad J. Agric. Vol.25, No.4.

Soloman, S., R. Salomon and J.S. Myles. 2005. Export and Domestic Sales: Their Interrelationship and Determinants, Strateg. Manag. J. Strat. Mgmt. J. 26: 855–871 (2005) Published online in Wiley Inter-Science (www.interscience.wiley.com).

Syrocki, B.J. 1961. Experimenting with Hydroponics, College of Education, State University of New York, Brockport 448, Published by: Univ. Calif. Press on behalf of the Nat. Assoc. Biol. Teach. Stable URL: http://www.jstor.org/stable/4439697

Tilman, A. and U. Eckhardt 2006. Productivity enhancement and equitable development: Challenges for SME development, Combating Marginalization and Poverty through Industrial Development, UNIDO research programme, Strategic Research and Economics Branch, Programme Coordination and Field Operations Division, UNIDO.

UN, 2015. Science, technology and innovation for sustainable development in the global partnership for development beyond 2015, Thematic Think Piece ITU, OHCHR, UNCTAD, UNEP, UNESCO, UNFCCC, UNIDO, WIPO, WMO, UN system task team on the post 2015 UN Development Agenda.

UN SDG. 2016. United Nation Sustainable Development, Knowledge Platform, Open Working Group Proposal for Sustainable Development Goals, https://sustainabledevelopment.un.org/focussdgs.html

United Nation. 2014. United Nation department of Economic and Social Affairs, Population Division, Population Estimates and Projection Section. http://esa.un.org/wpp/Excel-Data/population.html

United States Dept. of Labor 2014. Occupational health and safety administration, United State Department of Labor. https://www.osha.gov/pls/imis/sic_manual.htmls

Wikipedia (2015). a free encyclopedia. https://en.wikipedia.org/wiki/Net_farm_income