African Journal of Biotechnology Vol. 10(69), pp. 15538-15544, 7 November, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB10.2194
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Technology transfer for cucumber (*Cucumis sativus* L.) production under protected agriculture in uplands Balochistan, Pakistan

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Accepted 12 May, 2011

The adverse climatic conditions and scarcity of irrigation water in Balochistan (Pakistan) have encouraged the development of protected agriculture. Semicircular plastic tunnels were introduced in three districts of Balochistan. This technology transfer trials have shown the advantages and benefits of producing cucumber in tunnels with marketable yield per unit area between 5.37 to 6.77 kg m^2. Farmer-managed trials also confirmed better effectiveness and efficiency of protected agriculture tunnel against insect pest of cucumber grown under tunnel. The cucumbers so harvested were of higher quality (no insect damage) and were sold at premium prices during the whole production cycle. Proper crop sequencing by considering the market situations as well as physiological circumstances are important for successful production of high value crops including cucumbers round the year. These decisions should be based on the market demand and consumer preference analyses. Higher technical knowledge is also required to manage plant nutrient requirements, choose right kind of hybrids and irrigation scheduling, maintain temperature and humidity and take proper plant protection measures.

Key words: Cucumber production, protected agriculture tunnels, cost benefit ratio, technology transfer, upland Balochistan.

INTRODUCTION

Balochistan with an area of 34.7 million ha, represents 43% of the total area of Pakistan. The province has four distinct types of climates; coastal (sub-tropical), arid, hyper arid, and temperate, with a great diversity in altitudes and annual mean temperatures. The altitudes range from sea level to 1,800 m above sea level, and the mean monthly temperatures fluctuate from sub-zero in the winter months of December to January to super high (45 to above 50°C) in the summer months of May to July/August (Kidd et al., 1988). Annual precipitation fluctuates widely across the province; not only within a normal year but precipitation amounts are also erratic over a longer period of time (Athar, 2005).

Agriculture sector is the backbone of the economy of Balochistan, as it contributes about 32% of the provincial Grass Domestic Product (GDP). Agricultural outputs in the province have been expanding particularly since the mid 80's until towards the end of 90's when the impact of drought started causing significant decline on the overall output. Since 1998, total production of all crops has declined at an alarming rate of about 8% per year. At the same time, yields of most crops remained low as compared to other provinces or even other developing countries. The fluctuating level of water availability in the uplands is one of the several causes of relatively low yields of key vegetables. Inefficient use of irrigation water also adversely affects the per unit productivity of crops in

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the Balochistan province. As per government policy, and now with the availability of electricity at subsidized rates, there has been a tremendous increase in the number of tube wells.

However, as the conventional sources of water in the province were shallow wells, karees and springs therefore, indiscriminate installation of tube wells and pumping of water in excess of recharge have caused lowering of water table resulting in drying of dug wells, karees and springs (70%). The excessive pumping of ground water has caused serious concerns regarding the sustainability of irrigated agriculture. Since 1998, the International Centre for Agricultural Research in the Dry Areas (ICARDA) since 1998, has been involved in the development of protected agriculture in the water scarce countries of the Arabian Peninsula. Thus, they have initiated the same activities in Balochistan under the project "Food Security/Poverty Alleviation in Arid Agriculture Balochistan" - Pilot Project Phase. The plantation of cucumber in tunnels was one of the initiatives taken under this project.

Advantages of protected agriculture (PA)

Protected agriculture (PA) has the potential to contribute significantly to both the development of rural communities and to devise sound water policy for the production of high value crops of Balochistan. It can play an important role in supplying local markets with fresh produce that could not be grown otherwise, and in creating employment within rural communities and productive opportunities for the disadvantaged, particularly women. It also offers potential for development of a private service sector in the construction and supply of protected agriculture equipment and inputs such as seeds and fertilizers. Ultimately, high yielding quality produce from protected agriculture could be expanded to serve the export market and generate a valuable source of foreign currency.

PA with its associated production systems can significantly reduce the amount of water and chemicals used in producing high value fresh produce compared to open field production. The comparative advantages of PA over open field production may include:

1. Crops can be produced year round regardless of season, so multiple cropping on the same unit of land is possible. Farmers can benefit of market seasonality to produce off season crops to earn higher prices.
2. PA allows the production of high quality and healthy seedlings for transplanting to open fields, supporting earlier cropping and stronger, more resistant crop stands.
3. Protective housing provides protection for high value crops from unfavourable weather conditions, pests and diseases.
4. Use of PA can increase production by more than five fold, and increases productivity per unit of land, water, energy, and labour.
5. PA supports the production of high quality and clean products.

The strategic focuses of the current government plans are to augment and promote efficient use of limited underground water resources. PA initiative in this project was taken to examine the feasibility of water resource efficient high value agriculture. ICARDA has previously used this technology with farmers in Yemen and Afghanistan with promising results. There is substantial evidence that the PA technology is economically viable in the context of Afghanistan as well. In case of cucumber cultivation under PA, for example, its production in the spring of 2005 generated an additional farm income of Afs 13,200 to 78,000 per grower (ICARDA, 2006).

In Yemen, cucumber productivity was 17-fold greater under PA, while tomato reached 12-times its productivity as compared to open fields (Amin et al., 1998). Oweis (1990) studied cucumber yield response to different levels of irrigation and concluded that maximum yield of 946 tons/ha was produced with 223 mm of water consumed as transpiration. Thus, water efficient techniques of protected agriculture were successfully introduced by ICARDA to small landholders in the rainfed mountainous terraces of Yemen and Afghanistan, and the experience gained was transferred to Balochistan.

The overall aim of this study was to alleviate poverty and generate rural incomes, by promoting the adoption of affordable and sustainable Protected Intensive Production System (PIPS) to produce high value crops, using marginal or otherwise non-productive lands. The other objective was to estimate the economic feasibility of vegetable production under farm situations. The initial investment and operational cost were accounted for to estimate the gross revenue, total costs and net returns for the production and marketing of cucumber crop.

MATERIALS AND METHODS

In 2006, four galvanized and polyethylene (PE) covered green houses (9x30 m) having side and roof ventilation facilities were installed for vegetables production in three districts of Balochistan (Mastung, Killa Saifullah and Loralai). Generally, a large majority of growers liked this type of non-cooled greenhouse due to its simplicity and ease of construction. Tomato, squash and hot and sweet pepper were the main crops cultivated in these houses during the cool and mild seasons (Athar and Bokhari, 2006) but for the purpose of this experiment cucumber cultivation was considered due to its likely most economical crop under these tunnels.

A white net was used on both side of the tunnel to avoid any

Table 1. Initial investment for protected agriculture tunnel construction.

Item	Initial cost (US$)	%	Use full life year	Annual cost (US$)	%
Galvanized frame	1471.4	53	20	73.7	39
Plastic Covering	367.8	13	10	18.4	10
Insect proof net	313.4	11	20	15.7	8
Black plastic mulch	46.3	2	2	23.2	12
Sockets, valves, pipes, elbow etc.	118.2	4	10	11.8	6
T-Tapes and PVC pipes	108.1	4	10	10.8	6
Water tank	133.3	5	10	13.3	7
Water pump	100.0	4	15	6.7	4
Site preparation	50.0	2	10	5.0	3
Assembly	83.3	3	10	8.3	4
Total	2792	100		186.8	100
Per square meter	10.3			0.7	

insect damage and vectoring of diseases. In each tunnel, four rows were prepared with the distance of one meter. The total duration of the crop was around 100 to 120 days. In summer months, Limestone washing method was used at the roof for lowering the temperature during day time. Irrigation was done with trickle-irrigation. T-tubing was installed underneath the black plastic mulch with minute punctures for the water out-let near each plant. Cucumber Queen-1 variety was planted at all sites. The seed was imported from a Dubai based “Royal Sluis” company due to its good quality and high yielding reputation. Triple super phosphate was applied before planting. Compound soluble NPK fertilizers (nitrogen, phosphorus and potassium) were applied after 15 days of germination at the recommended rates with irrigation on alternate days.

Plants were individually trellised on twine hung from a horizontal support. Plastic clips were used to attach the vines to the twine at the base of the plant and along the vine to support the fruit load. Cucumbers were pruned to a single stem with no lateral branches (suckers). Fruits were removed up to the 6th to 8th node and the plants were then allowed to set one fruit per node every other node up to the horizontal support. At the top of the support wire, two laterals were trained over the wires. However, cucumbers set multiple fruits at each node and on the lateral branches, so both the fruit and lateral branches were left on the plant after the 8th node to avoid excessive vegetative growth and lateral branches were pruned at the second node on the lateral. Disease and insect controls were monitored continuously as per recommended practices. The poor quality fruit were removed before maturity which also helped in maintaining continuous fruit set. Cucumbers were harvested at a diameter of 4 cm or less.

For the purpose of cost-benefit ratio analysis, all costs including initial investment on protected agriculture (PA), its installation cost, variable cost of cucumber production and fixed costs were accounted. The PA was constructed near tube well water already installed by the farmer. However, a water pump and water tank was put in place for irrigation purposes. The irrigation supply was metered to estimate the m^3 water usage during crop production period. The field was thoroughly ploughed with the tractor before installing PA.

Fixed costs were included as interest (7%) on total initial investment, annual initial investment cost (4 months) and interest on total variable cost (7%). Variable costs covered ploughing, ridge making, seed, fertilizers, pesticides, micro-nutrients, picking labor, haulage and packing costs. Administrative costs were estimated for managing production operations and marketing of produce. Depreciation of PA was estimated by using the straight-line method. Assets were divided by their useful life expectancies to determine annual cost for depreciation. The land rent was ignored in this study, as land used for the installation of PA was not previously under use for agriculture purposes.

Thus, total production costs of cucumber production in PA were the combinations of fixed costs, variables and managerial costs. The net returns were estimated by subtracting total costs from the gross revenue of cucumber produced and sold at different prices during the whole production cycle. Monthly average weighted prices were used to estimate gross returns from the total production.

RESULTS AND DISCUSSION

Investment and variable costs

The initial investment costs, annual costs, variable costs and total costs of cucumber production in tunnels are presented in Tables 1, 2 and 3, respectively. Initial investment costs were calculated to be US$ 2,792 for 270 m^2 tunnel or US$ 10.3 per m^2. About three fourth of the initial investment cost was comprised of galvanized frame, plastic covering and insect proof net. Annual initial investment cost was US$ 187. It was assumed that three crops could be grown by the farmers under mild temperature conditions prevailing during the summer season. As cucumber cultivation was completed in 4 months period, therefore, annual investment cost estimated of US$ 62.3 was estimated.

Low cost low tunnels are presently used in Balochistan to grow tomato nurseries for early planting only. Such low tunnels are very commonly used around Nowshera area of Khyber Pakhtoon Khawah province of Pakistan to grow off-season cucumber and squashes. The cost of polyethylene sheets and sticks used to cover cucumber during early growth stages is estimated around US$ 208 per ha (Adnan, 2006; Ishaq et al., 2003). Under low

Table 2. Variable cost for cucumber production in protected tunnels.

Parameter	Unit	Rate (US$)	Amount (US$)	Total cost (US$)	%
Tractor ploughing	Hour	5.0	2.0	10.0	7
Ridge making	Man day	3.3	1.0	3.3	2
Seed	No	0.1	595.0	49.6	33
Fertilizer	Kg	0.8	28.4	23.4	15
Irrigation labor	Man day	1.7	13.3	22.1	15
Electricity charges	Per cubic meter	0.3	39.0	13.0	9
Picking labor	Man day	1.7	4.1	6.9	5
Pesticide	Cost	1.0	6.7	6.7	4
Micro-nutrients	Cost	1.0	3.1	3.1	2
Haulage	Cost	1.0	11.0	11.0	7
Packing cost	Crate	0.4	5.0	2.2	1
Total				151.2	
Per square meter				0.6	

Table 3. Total cost of cucumber production in PA.

Parameter	Total cost (US$)	%
Variable cost	151.2	49
Fixed cost	------	0
Interest on total initial investment	64.5	21
Annual initial investment cost	61.6	20
Interest on total variable cost	10.6	3
Sub-total	137.7	44
Managing cost	20.0	6
Grand Total	307.9	100
Per Square meter	1.14	

tunnels, cucumber yields were 3.7 kg, total cost US$ 0.32, and net benefits US$ 0.23 per m^2 on farmers' field in Nowshera area of Khyber Pakhtoon Khawah province (Adnan, 2006).

Ordinary high tunnels were conventionally used by the research system to explore the possibilities of growing off-season vegetables including cucumber, tomato and sweet peppers. Chaudhry et al. (2003) tested 11 cucumber hybrids growth in tunnels during winter season in rainfed Pothwar. The use of high tunnels either made with local materials like bamboo sticks or PVC pipes and plastic covering is becoming increasingly popular in the Punjab province of Pakistan. Use of high efficiency tunnels is a rare phenomenon and limited with some hybrid seed importer for testing new hybrids and to demonstrate the commercial production of high value off season vegetable crops. The cost of material used ranges between US$ 2 to 10 per m^2. The variable cost incurred for the production of cucumber during summer season is shown in Table 2. Total variable costs for growing cucumber were estimated to be US$ 151. Variable cost per square meter was calculated to be less than a dollar. The share of seed cost in total variable cost was 33%. Fertilizer and irrigation labor cost was identical (15%). Pumping of water with tube wells was highly subsidized in Balochistan.

Therefore, the cost of 39 m^3 water used during the whole production season was US$ 13 only. Packing cost was minimal because the same two plastic crates were used during the whole production cycle. The labor cost accounted for irrigation, picking, packing and marketing were also substantial and have important implications towards adopting labor intensive high value crops production under PA (Elahi et al., 1983). The total cost associated with the production of cucumber in tunnel is summarized in Table 3. Total cost of production was determined to be US$ 308. Total cost per square meter was US$ 1.14. Share of variable, fixed cost and managerial costs were 49, 44 and 6%, respectively. The cost incurred per kg of cucumber produced in PA was estimated around $ 0.26. About 1830 kg of cucumbers were produced by spending $ 308.

Marketing of produce

Greenhouse-grown vegetable crops have become more popular in recent years because of their higher yields, quality, and value (Dinham, 2003). Despite a new technology in Balochistan, without having any vast experience, the overall yield of cucumber was quite encouraging at all locations and yield per unit area was from 5.37 to 6.77 kg m^2. The cucumber yield can be

Table 4. Total gross revenue obtained from cucumber production in PA.

Month	Yield (kg)	Price ($/kg)	Gross revenue ($)
February to June	1080	0.299	322.9
July to October	750	0.401	300.7
Total	1830	0.350	622.6
Per Square Meter	6.77	2.31	

compared with Afghanistan PA established by ICARDA in 2005, where the cucumber yield for a square meter ranged from 1.9 to 12 kg on average 5.3 kg/m^2 (ICARDA, 2006). The low yield was observed at Saddiqabad due to 12 to 16 h of load sheding in the area which affected the availability of water. It must be noted that this income was from two cropping seasons and these tunnels could be utilized for at least three cropping seasons per year. Although the initial cost of materials for tunnel may be high, farmers will be able to recover this cost in the long run, as they continue using the tunnel over several growing seasons. Plant disease remains the leading drawback for greenhouse vegetable production (Dinham, 2003).

Cucumbers were marketed in the nearby town market of Mastung, Killa Saifullah and Dukki. The produce was transported instantly after harvest in plastic crates. The cucumber produced in PA was clearly distinguished from the open field produced ones. Therefore, disposal of produce was quite easy even in a small local market. The produce was easily distinguished by the buyers and sold at premium prices during the whole production cycle. The prices in the local market were negotiated on per crate basis that is equal to 18 kg weight. The average premium received per crate was around US$ 2 (30 to 40% higher prices) per crate. During the peak supply periods of August, prices received were lower and increased significantly during September and October months. Average prices received ranged between US$0.30 to US$ 0.46 per kg. About 58% cucumber was sold at US$ 0.30 per kg and the rest was sold at higher prices (Table 4). It could be concluded that marketing of cucumber produced in tunnels was readily accepted in the local market. Buyers were found willing to pay a 30 to 40% price premium for the tunnel produced high quality delicious cucumbers.

Sensitivity analysis of minimum yield to achieve break-even

A sensitivity analysis is one of the better alternatives to understand uncertainty in any type of financial model. Sensitivity analysis shows the financial situation of a certain enterprise when produce price changes or input prices change (Weinberger and Lumpkin, 2005). For the successful greenhouse production, it is important that produce's price covers at least the unit production cost. Based on current production costs inside 270 m^2 greenhouse and because growers cannot influence the market price, a sensitivity analysis was conducted to indicate the minimum yield required at a given market price to cover production costs (Chaudhry and Ahmad, 2000; Dinham, 2003; Hussain and Hanif, 1990). The results showed that cucumber producers should target yields above 700 kg for summer sales when prices could be as low as US$ 0.35 per kg. In the winter yield should be above 260 kg when the price is expected to be more than US$ 0.70 per kg (Figure 1).

Gross revenue and net returns

Total gross revenue earned from producing cucumber under PA was estimated to be US$ 623 (Table 5). Total cost of cucumber production was estimated to be US$ 308. A share of variable and fixed cost in total cost was almost identical. Net returns were estimated to be US$ 315. Net returns per square meter were estimated to be US$ 0.37. Total irrigation water resources used to produce 1183 kg cucumber was 39 m^3. Net return per cubic meter water was estimated to be US$ 2.88, whereas in Afghanistan it reached US$ 3.68, which clearly indicated the potential to also improve water use efficiency in Balochistan.

Conclusions and recommendations

Vegetable production in high technology tunnels is a challenging task on technical as well as economic accounts. Proper crop sequencing by considering the market situations as well as physiological circumstances are important for successful production of high value crops round the year. These decisions should be based on the market demand and consumer preferences analyses. Higher technical knowledge is required to manage plant nutrient requirements, choose the right kind of hybrids and irrigation scheduling, maintain temperature and humidity and take proper plant protection measures. The project has achieved some milestones in the introduction of water use efficient PA that includes:

(i) Exposure of scientific cadre to manage high value crops in tunnels;

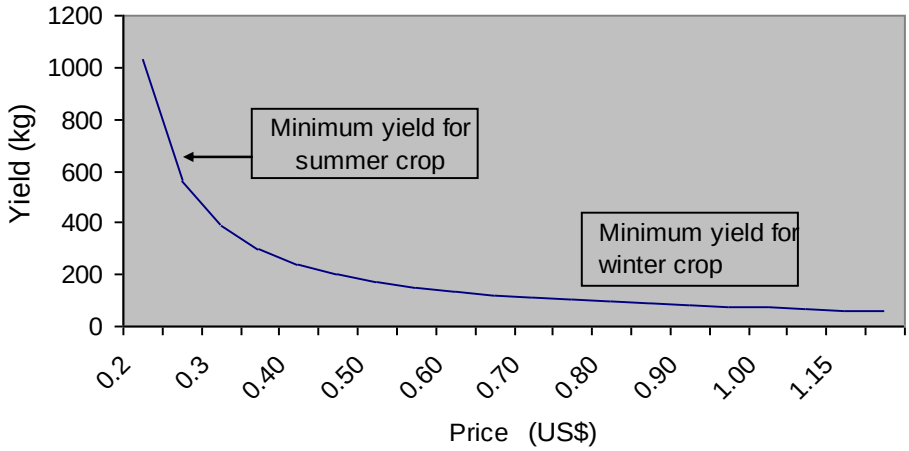

Figure 1. Minimum yield for given prices to break-even in cucumber production under greenhouse.

Table 5. Net return obtained from cucumber production from PA.

Item	Total value ($)	Proportion of revenue (%)
Total Gross Revenue	622.6	100
Variable cost	151.2	24.28
Fixed cost	156.7	25.17
Total cost	307.9	12.17
Net Return	314.7	50.55
Net return per square meter	1.16	
Net return per cubic meter water	2.88	

(ii) Training of technicians in assembling and installing of all components of tunnels at farmers fields;
(iii) Understanding on forming beds and planting crops with mulching;
(iv) Controlling high temperature during summer;
(v) Handling pest problems; and
(vi) Adjusting the use of soluble NPK by considering crop condition at different growth stages.

The PA farmers and researchers are linked to seed dealers dealing with the supply of hybrids who supply after testing these seeds at their own farms. The hybrid dealers also have vast experiences of growing vegetables under tunnels at commercial scale. These linkages would benefit the research system of Balochistan through sharing their experiences and also provide low cost viable hybrid seeds tested under local circumstances.

The net returns from cucumber production under PA shows its feasibility even with low level of technical knowledge during initial experimentation phases. Vegetables are exported from Balochistan for 4 months and during the remaining 8 months imported from other provinces. The consumer at the local markets located at Mastung, Killa Saifullah and Loralai districts can easily distinguish between the quality of produce from PA and open fields. Consumers are also ready to pay premium for the quality products produced under PA which shows potentiality of increasing high value crops production under high tech tunnels. Higher net returns obtained for per cubic meter of water used to produce high quality cucumber, further suggest the expansion of high value crops production under PA.

REFERENCES

Adnan P (2006). Comparative analysis of seasonal and off Cucumber in Nowshera, Charsadda and Malakand areas of NWFP. Department of Agricultural Economics, Faculty of Rural Social Sci. NWFP Agricultural University, Peshawar, Pakistan

Amin AH, Al-Kirshi T, Abbas AM (1998). Protected agriculture in the Republic of Yemen. {Moustafa A, Al Mohammadi A, Abou-Hadid A and Peacock JM, (eds.)}. Proc. International Workshop 15-18 February 1998. Doha, Qatar.

Athar M (2005). Nodulation of native legumes in Pakistani rangelands. Agric. Consp. Sci. 70: 49-54.

Athar M, Bokhari TZ (2006). Ethnobotany and production constraints of traditional and commonly used vegetables of Pakistan. J. Vegetable Sci. 12: 27-38.

Chaudhry MF, Khokhar KM, Jeelani G, Ullah U Riaz S (2003). Performance of some cucumber hybrids/lines under plastic tunnel. Sarhad J. Agric. 19: 493-495.

Chaudhry MG, Ahmad B (2000). Pakistan. In: Dynamics of vegetable production, distribution, and consumption in Asia. {Mubarik A (ed.)}.

Asian Vegetable Research and development Center (AVRDC), Shanhua, Taiwan, AVRDC Publication No. 00-498. pp. 271-302.
Dinham B (2003). Growing vegetables in developing countries for local urban populations and export Markets: Problems confronting small scale producers. Pest Manage. Sci., 59: 575-582.
Elahi M, Khan MJ, Rehman H (1983). Rural Labor Market with special Reference to hired labor in Pakistan's Punjab. Punjab Economics Research Institute, Lahore.
Hussain AR, Hanif M (1990). Vegetable research in Pakistan. In: vegetable research and development in south Asia; { Shanmugasundaram S (ed.)}, Asian Vegetable Research and development Center (AVRDC), Shanhua, Taiwan, AVRDC Publication No. 90-331. pp. 52-57.
ICARDA (International Center for Agricultural Research in the Dry Areas). (2006). Introducing protected agriculture for cash crop production in marginal and water deficit areas of Afghanistan. Final Report. ICARDA, Aleppo, Syria.
Ishaq M, Sadiq G, Saddozai SH (2003). An estimation of cost and profit functions for offseason cucumber produce in district Nowshera. Sarhad J. Agric. 19:155-161.
Kidd CHR, Rees DJ, Keatings JD, Rehman F, Samiullah A, Raza SH (1988). Meteorological data analysis of Balochistan. Research Report No 19. AZRI/ICARDA, Quetta, Pakistan.
Oweis TY (1990). Irrigation management of plastic house cucumbers. Dirasat. 17B: 59-71.
Weinberger K, Lumpkin TA (2005). Horticulture for poverty alleviation- The unfounded revolution. Asian Vegetable Research and Development Center (AVDRDC), Shanhua, Taiwan, AVRDC Publication No. 05-613, Working Paper No. 15. p. 20.