Proceedings of the Pakistan Academy of Sciences: Part B
Life and Environmental Sciences 59(1): 57-68 (2022)

ISSN (Print): 2518-4261; ISSN (Online): 2518-427X
http://doi.org/10.53560/PPASB(59-1)690

Pakistan Academy of Sciences

Research Article

Adoption and Cost-benefit Analysis of Drip Irrigation for Production of High-Value Crops in Pakistan

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Abstract: Drip irrigation is regarded as one of the highly efficient methods that allow limited water resources to be properly utilized. The study has been conducted to perform the economic analysis of low and high head drip irrigation systems throughout the country based on data from 100 adopters of drip irrigation through a research & development project funded by the International Center for Agricultural Research in the Dry Areas (ICARDA-Pakistan)/United States Department of Agriculture (USDA). A field survey for the study was conducted in the year 2018 in all the provinces of Pakistan. The study revealed that technology is generally adopted by the farmers having diversified income sources and medium-sized land holdings i.e. ranging from 12.5 to 25 acres. System installation cost-shared 11 percent in low-head drip system of the annual production cost of fruits. While, it shared 29, 32, and 27 percent in case of a high-head system for grapes orchards, vegetables in tunnels, and open fields, respectively. Low-head drip irrigation is profitable for dates/ lemon orchards in Khyber Pakhtunkhwa with a benefit-cost ratio (BCR) of 1.27:1.00. It results in considerable profitability for grapes orchards with BCR of 1.73:1.00 and 1.32:100 in Punjab and Balochistan provinces, respectively. The low-head system is also beneficial for mixed fruit orchards in rain-fed Punjab with a BCR of 1.24:1.00. Similarly, for high-head systems, the benefit-cost ratio was the highest for grapes produced in rain-fed Punjab (2.62:1.00), followed by squash-gourd in irrigated Sindh (2.17:1.00) bitter-gourd in rain-fed Punjab (1.50:1.00) and okra in Sindh (1.22:1.00). However, low and high-head systems could not result in considerable returns for farmers in the case of mixed fruits in Balochistan and cucumber production in tunnels in Punjab province during the study year.

Keywords: Adoption, Benefit-cost ratios, Drip Irrigation, Fruit, High-head, Low-head, Pakistan, Vegetable

1. INTRODUCTION

Optimizing the use of water is critically important for the socioeconomic uplifting of people and the development of any country. In this perspective, increasing water scarcity and efficient use of existing water resources is becoming a global challenge [1]. As, irrigation is the artificial application of water to crops through appropriate methods such as surface (basin, border, furrow), or pressurized (sprinkler, bubbler, drip) irrigation systems [2]. While, the irrigation system of Pakistan comprises of three major reservoirs, 16 barrages, two headworks and syphons each, 12 link canals, 44 canal commands, and more than 140,000 watercourses. Although Pakistan possesses one of the largest contiguous gravity flow irrigation networks, but it is confronted with many issues such as low irrigation efficiency and water productivity, under-designed capacity, old infrastructure requiring extensive maintenance, water scarcity, inequity, etc. [1]. Basin or flood irrigation has the lowest irrigation efficiency (40-50 %), while overhead methods like sprinkler and drip/trickle are efficient in irrigation application by 60-65 % and up to 90 %, respectively [2].

It is believed that an increase in water requirement due to the rising population and

Received: November 2021; Accepted: March 2022
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increasing demand for industrial usage may limit the increase in agricultural productivity. One of the options for future water needs is to use available water resources more efficiently and effectively for the production of staple crops in general and high-value crops in particular [3]. Alternatively, there should be rationing on payment of the price for water management. We need to find out the solutions without hurting socio-political sensitivities. That is possible with superior strategic management through the use of appropriate technologies and awareness amongst citizens in general and farmers in particular [4]. High-efficiency irrigation system (HEIS) is an option to meet future water needs, as it results in the efficient and effective use of precious water resources, which are being overexploited. The systems are adopted in Kenya and neighboring countries to combat periodic droughts and alleviate food security for thousands of people [5]. Similarly, large-scale adoption of HIES alongside low-cost greenhouse farming technology by smallholder farms in rain-fed countries is reported [6]. HEIS such as sprinkler and drip have several advantages over surface irrigation, such as; high application efficiency & productivity, better quality production, low energy requirements, reduced soil salinity hazard & weed growth, fewer disease problem, and can be highly automated [2]. Similarly, the overview of the current water availability and irrigation system in the country highlighted drip irrigation technology as an alternate solution for sustainable irrigated agriculture [7]. Similarly, it is reported that the technology produces more crop yield by one-fourth with more than half of water use in rain-fed areas of Sindh [8]. Likewise, it is stated that the adoption of water-efficient technologies and diversifications to higher-value crops help accelerate agricultural water productivity [9].

HEIS allows water near the plant roots either onto the soil surface or beneath the soil surface directly to the root zone area. Thus, the use of HEIS also minimizes soil erosion. Application of irrigation water as well as agrochemicals according to crop requirements is possible through the system. HEIS can irrigate irregular-shaped fields without proper land leveling, as is necessary in the case of basin, border, and furrow irrigation methods. The drip irrigation allows safe use of recycled water; maintains moisture within the root zone near the field capacity. Even, the soil type plays a less important role in the frequency of irrigation application in this method. The other advantages of drip irrigation include a highly uniform distribution of water i.e. controlled by the output of each nozzle. The water system is regulated through valves and drippers hence labor cost is minimum [10].

Through HEIS, water which lies beneath the earth's surface or not at the proper height from the field surface is provided through suitable pressure generated by electricity or diesel pumps. This passes through main, sub-main, lateral lines and emitters in a sequence and reaches in drops near plant roots. Emitters are placed at a recommended distance for different vegetables. Similarly, the use of lateral pipes with holes at suitable gaps is also becoming popular. As fruit and vegetables are usually planted in rows, thus they can be easily irrigated through this system. This system can also be used with mulching in open fields or tunnels [11]. Through this system, farmers can use available irrigation water in a better way to obtain higher productivity and profitability from tunnel farming. It is quite simple technology, which is most efficient and easy to use, increases crop yield up to 25 percent; applicable for vegetables, orchards, and cotton crops; and is equally suitable for kitchen gardening [12]. Similarly, drip irrigation provides the salinity control for the profitable irrigation of vegetables [13]. These systems, however, also have some constraints such as high initial cost, maintenance requirements, restricted plant root development, salt accumulation near plants (along the edges of the wetted zone), application of insoluble or slightly soluble fertilizers such as Super Phosphate or Sulphate of Potash is not readily possible [2]. While the most severe problem is the clogging of emitters by particulate and biological materials and this can cause poor application uniformity [14]. However, flushing the system after each cropping season can solve this problem [2].

Since 1985, the Government of Pakistan has initiated several projects to promote sprinkler and drip irrigation systems in the country. However, most of these projects could not achieve the intended objectives due to; high capital cost, non-availability of material, no backup support, complicated/ over-designed systems, small landholdings, and lack of knowledge about irrigation scheduling (when to apply and how much water to apply to crops),

farmers' misconception about the system, and a flat rate of electricity in case of Balochistan. Therefore, for the success of these systems, the selection of the right area, right crop, right farmer, right material, and right design are very important. Moreover, the design of the system should be simple, so that common farmers can easily maintain and operate it. Potential areas for these systems include the Pothwar plateau, desert, semi-desert areas, uplands of Balochistan, riverine belts, greenhouses, and tunnels [2].

Low-head drip irrigation systems are generally permanent and have low labour and energy requirements [14]. Low head drip irrigation is a viable technology for rain-fed areas, as its use helps farmers to efficiently use limited water resources in these semi-arid and arid areas [15]. Low-head drip irrigation for high-value orchards is being promoted by the Pakistan Council of Research in Water Resources (PCRWR) Head Quarters, Islamabad, and its Regional Office, Peshawar and Regional Office, Quetta, also called Water Resources Research Centre (WRRC) in rain-fed areas of Punjab (Attock, Rawalpindi and Chakwal districts), Khyber Pakhtunkhwa (Dera Ismail Khan district) and Balochistan (Quetta, Mastung and Killah Abdullah districts), respectively. High-head drip systems have high energy requirements as water storage is generally more elevated than low-head systems thus water supply is also more pressurized. Soil and Water Conservation Research Institute (SAWCRI), Chakwal and Climate, Energy and Water Research Institute (CEWRI), PARC-National Agricultural Research Centre, Islamabad promotes high-head drip irrigation for orchards in rain-fed areas of Punjab (Chakwal district). Similarly, high-head drip irrigation systems for vegetables are being promoted by the Institute of Water Resources Engineering and Management (IWREM), Mehran University of Engineering and Technology (MUET), Jamshoro with the support of a local support organization, named Rural Development Foundation (RDF) in the irrigated area of Sindh province (Jamshoro district).

Keeping in view the water scarcity situation in the country, the International Center for Agricultural Research in the Dry Areas (ICARDA) and the United States Department of Agriculture (USDA) launched the project 'Diffusion and adoption through partnership and action of the best watershed rehabilitation and irrigation practices and technologies to help rural farmers' to promote adoption of HEIS and other water saving/ soil moisture conservation technologies. ICARDA, Pakistan office through local technical partner institutes viz. PCRWR, PARC, SAWCRI and MUET disseminated the pertinent knowledge and demonstrated drip irrigation systems throughout the country in the first phase of the project (2014-16). In the second phase (2017-18) farmers were convinced to adopt HEIS by developing their linkages with materials /service providers, and technical experts, and also by providing subsidies at a rate of 60:40, i.e. 60 % of the cost was borne by the ICARDA/USDA in Dera Ismail Khan district, and Jamshoro district of Sindh, at a rate of 70:30, i.e. 60 % of the cost was borne by the ICARDA/ USDA and 10% was borne by RDF. Subsidy for the adoption was provided to the farmers keeping in view their resource poverty at both sites, and also due to the tough terrain of the area in the Dera Ismail Khan district. Consequently, a considerable number of adoptions were reported from different institutes including PCRWR, CEWRI-PARC, SAWCRI, etc. As very little has been published about the cost-benefit analysis and adoption of the technology in the country. Thus, the article is an effort to document the demographic characteristics and livelihood sources of the adopters; their knowledge level and adoption of the technology, area allocation to drip systems, and cost-benefit analysis of the technology across provinces. The findings of the research work are helpful for public/ private sector stakeholders to fine-tune their plans/ policies to up-scale adoption of the technology in the country, and for farmers to adjust their investment priorities in drip irrigation.

2. MATERIAL AND METHODS

The study is based on a field survey, data collected from 100 adopter farmers (about 17 % of a total, 597 adoptions) that were randomly interviewed out of the lists of the adopters provided by the technical institutions promoting the technology in the country. The sample for the study has been drawn based on number of total adoptions, spread of adoptions and availability of human, financial and logistic resource by PARC Satellite institutes, Social Sciences Research Institute in Islamabad, and countrywide technical partners. The sample for

the study includes 50 farmers each of low-head and high head drip irrigation systems. Field surveys for the study were conducted from January 2018 to May 2018 through a set of well-structured and pre-tested questionnaires that were prepared in consultation with technical experts and socio-economists from regional offices of ICARDA in Pakistan and Jordan, as well as technical experts from national and provincial agricultural research systems. Detailed questionnaires were developed for the study to obtain information about farmers' knowledge about the technology, their practical experiences, suitability of the technology in the study areas, economic gains of adoption, and adoption potential covering fellow farmers' interest in its adoption and possible constraints in up-scaling of the technology.

Distribution of the sample respondents across provinces along with details about the type of drip irrigation system, commodities (fruits and vegetables), etc. are presented in Table 1. In rain-fed areas of the Punjab and Balochistan provinces, low-head systems are used for high-value orchards of grapes and other fruits. While, in rain-fed areas of Khyber Pakhtunkhwa province, the system is used for date and lemon orchards that are generally planted in a mix. While high-head systems are used for grapes, tunnel farming of cucumber and bitter-gourd in rain-fed Punjab, and for production of okra and squash gourd in open fields in irrigated areas of Sindh. Details about sample farmers across provinces along with study areas and orchard types are presented in Table 1.

Low-head drip irrigation technology has been promoted through financial support/subsidy in the Dera Ismail Khan district of Khyber Pakhtunkhwa. Thus, sample farmers are inquired in detail about the establishment and maintenance costs of high-value orchards. Date plants generally take three to five years to bear a marketable level of the produce, thus production, marketing, and income data were substantiated by the information about already established fruit-bearing orchards in the study area, that were mature enough and in the full fruit-bearing stage. In this region and other parts of the country, along with thorough information that was collected through structured questionnaires, detailed information about a few aspects of adoption prospects of the technology has also been obtained through discussion with the respondents. The data has been analyzed for descriptive statistics and cost-benefit analysis through SPSS-22 and MS-Excel, respectively.

3. RESULTS AND DISCUSSION

Adopter farmers of HEIS were in the middle age group, with a mean age of 42.2 years and formal education of 9.5 years (Table 2). They were involved in crop and fruit farming for a long period of time, with a mean farming experience of 18.0 years. Mean family size of the sample farming households was 8.9. Mean operational holding of the farmers was 14.8 acres. This means that generally the technology is adopted by medium-size farms, having landholding of greater than 12.5 acres. Thus, small farmers could not adopt it, while

Table 1. Distribution of the sample across provinces with type of drip irrigation system

Type of System	Province	District (s)	Study Area (Villages)	Orchard Type	Sample Size
Low-head system for high value orchards (Rain-fed)	Khyber Pakhtunkhwa	Dera Ismail Khan	Wanda Feroz & Panyala	Dates/ Lemon	10
	Punjab	Attock	Narthopa, Salar, Pandak & Malikmal	Grapes & Mixed Fruit	20
		Rawalpindi	Wah/ Wah Gardens Town		
		Chakwal	Dhok Darbi		
	Balochistan	Quetta	Bazee, Merabzae, Hassanabad & Sajawalabad	Grapes & Mixed Fruit	20
Sub-total					50
High-head system for orchards and vegetables (Rain-fed)	Punjab	Chakwal	Thati Gujran & Fatehjang	Grapes,	30
				Cucumber & Bitter-gourd	10
High-head for orchards and vegetables (Irrigated)	Sindh	Jamshoro	Bhit Kacchi & Shirabad	Okra & Squash-gourd	10
Sub-total					50
Total					100

large farmers usually rely on major crops for their income, and do not prefer to adopt capital-intensive and technical skills requiring technologies. The average area under drip irrigation at the sample farms was 4.2 acres, 67.7 % of the irrigated area at these farms. Drip irrigated area as a percent of the total irrigated area was minimum in irrigated Sindh (19.2 %). While in rain-fed areas of Khyber Pakhtunkhwa and Balochistan irrigated area was solely limited to drip systems. As the adoption of technology is mainly limited to rain-fed areas, thus due to the limitation of cropland farming families keep livestock in very limited numbers, with a mean number of animals at sample farms of three. Technology type and province-wise details are presented in Table 2.

Sample farming households have diversified sources of livelihood. Details about income sources along with contribution to the total income of the sample farmers by regions are given in Table 3. Crops' share in the income of the sample farmers who have had installed drip irrigation systems at their farms was 55 % followed by job and remittances (19.4 %), small enterprises and trade (14.2 %), livestock (9.2 %), and farm labour and services (2.2 %). The share of the crop income of farmers was the highest in Balochistan (99 %), followed by in irrigated Sindh (55.7 %) and rain-fed areas of Punjab (43.3 %) and Khyber Pakhtunkhwa (39.0 %). Livestock shared the highest in irrigated Sindh (27.7 %) followed by rain-fed areas of Punjab (9.9 %) and other provinces. Farm labour and services as well as small enterprises and trade shared the highest income of the farmers in rain-fed areas of Khyber Pakhtunkhwa (11.0 %). While job and remittances contributed to the maximum income of farmers in rain-fed areas of Punjab (42.3 %).

ICARDA-USDA funded initiative for the promotion of drip irrigation created awareness in far-flung areas of the country. All the sample farmers in Balochistan, Khyber Pakhtunkhwa, and Sindh provinces reported that technical persons working on the project made them aware of the benefits of the adoption of the technology (Table 4). In Punjab province, On-Farm Water Management (OFWM) department has created awareness in the farming community about the technology on a large scale. About half of the sample adopter farmers (49 %) reported obtaining proper training in drip system installation. Farmers' adoption experiences vary greatly across provinces, with the lowest of one year in Sindh to the highest of 4-5 years in Punjab. Availability of technical support for installation as well as for repair and maintenance of the systems was excellent in Punjab and Sindh provinces, with 100 % response by the farmers about access to these services. While, one-third and half of the sample farmers in Khyber Pakhtunkhwa and Balochistan provinces reported access to technical support services about the technology, respectively. The interest level of the fellow farmers of the adopters in the technology was medium to high (Table 4).

In the case of a low-head drip system in Khyber Pakhtunkhwa, as far as access to market and enabling institution is concerned, materials and equipment for drip irrigation are not available in local markets and farmers are to purchase these mostly from Peshawar. However, the mean distance of local input markets from sample farms was five kilometers. One-third of the farmers (33%) reported that technical support for the adoption of the technology is readily available to them, and they have access to at least two Agricultural Service Providers (ASPs) or technicians in their vicinity. All these farmers declared that the availability of services for installation, repair, and maintenance of the drip irrigation systems are sufficient to fulfill their requirements.

Farms of the sample adopters in the case of low-head drip irrigation in Punjab were located far away from local input as well as output markets, with an average distance of more or less 40 km for each. While the mean distance of the farms from non-local input/output markets was 119 km. The main constraints in the adoption of the technology on large scale in the study area are the high cost of installation of the system, non-availability of material in local markets, and lack of services of technical people /ASPs, as reported by 33 percent of the sample farmers each. In the case of a drip irrigation system for fruit plants in the province, sample respondents reported that at least one of their fellow farmers adopted the technology by looking after its success on their farms. They reported that they have access to two to three ASPs each; however, as most of these are serving the drip system installation companies, they are only occasionally available to them.

Table 2. Demographic characteristics of the farmers

Characteristics		Low-head Systems		High-head Systems		Total	
		Khyber Pakhtunkhwa (n=10)	**Punjab** (n=20)	**Balochistan** (n=20)	**Punjab** (n=40)	**Sindh** (n=10)	**Pakistan** (n=100)
Age (year)		46.3 (15.9)	37.0 (8.2)	42.8 (7.6)	40.0 (11.9)	44.8 (11.0)	42.2 (10.9)
Education (year)		8.0 (6.9)	8.7 (5.2)	9.7 (4.5)	11.0 (5.1)	10.0 (2.8)	9.5 (4.9)
Farming experience (year)		18.3 (14.4)	11.8 (7.1)	16.3 (15.0)	17.7 (14.2)	26.0 (9.6)	18.0 (12.1)
Family size (number)		7.0 (2.8)	7.2 (3.8)	13.2 (4.2)	8.2 (3.9)	8.8 (2.4)	8.9 (3.4)
Operational land holding (acre)	Total	11.4 (9.9)	11.6 (7.9)	10.4 (4.0)	35.3 (32.6)	5.2 (2.0)	14.8 (11.9)
	Rain-fed	10.1 (9.6)	4.2 (6.7)	3.0 (4.7)	25.9 (27.7)	0.0 (0.0)	8.6 (10.4)
	Irrigated	1.2 (0.7)	7.4 (6.9)	7.4 (2.0)	9.4 (5.7)	5.2 (2.0)	6.2 (3.2)
Drip irrigation area (hectare)		1.2 (0.7)	6.4 (1.7)	7.4 (6.9)	3.0 (2.0)	1.0 (0.7)	4.2 (3.0)
Drip area as % of op. holding		100.0	86.5	100.0	31.9	19.2	67.7
Livestock holding (number)		4.0 (2.0)	2.8 (3.0)	0.5 (0.8)	3.5 (4.6)	5.0 (4.3)	3.2 (2.3)

Source: Field Survey 2018, Pakistan Note: Figures in parenthesis are standard deviations

Table 3. Sources of Income (percent)

Sources	**Low-head Systems**		**High-head Systems**		**Total**	
	Khyber Pakhtunkhwa (n=10)	**Punjab** (n=20)	**Balochistan** (n=20)	**Punjab** (n=40)	**Sindh** (n=10)	**Pakistan** (n=100)
Crops	39.0	38.2	99.0	43.3	55.7	55.0
Job & Remittances	13.2	42.3	0.0	34.2	7.4	19.4
Small enterprises & trade	35.7	13.3	0.0	12.6	9.2	14.2
Livestock	1.1	6.2	1.0	9.9	27.7	9.2
Farm labour & services	11.0	0.0	0.0	0.0	0.0	2.2

Source: Field Survey 2018, Pakistan

Table 4. Knowledge of the technology and its Adoption

Characteristics		**Low-head Systems**		**High-head Systems**		**Total**	
		Khyber Pakhtunkhwa (n=10)	**Punjab** (n=20)	**Balochistan** (n=20)	**Punjab** (n=40)	**Sindh** (n=10)	**Pakistan** (n=100)
Source of information (%)	Project	100	10	100	17	100	49
	OFWM	-	90	-	83	-	51
Trained (%)		33	60	33	17	100	49
Experience (years)		2.0	5.0	2.0	4.0	1.0	3.0
Technical Support (%)		33	100	50	100	100	83
Fallow farmers' interest (%)	High	0	70	0	67	80	49
	Medium	30	30	80	33	10	39
	Low	70	0	20	0	10	12

Source: Field Survey 2018, Pakistan

Drip irrigation technology is quite new for the adopter farmers in Sindh province, as they reported to get knowhow about it since the end of the year 2017 through farmer field days organized by Institute of Water Resources Engineering and Management (IWREM), MUET, Jamshoro in collaboration with a Local Support Organization (LSO) named Rural Development Fund (RDF). They declared these events very much informative and effective in dissemination of the knowledge about the technology. All the sample farmers reported attending training programs jointly organized by IWREM and RDF on drip irrigation for vegetables. All of them reported visiting demonstration sites/ fields of their fellow farmers to practically witness the working of the technology. Sample farmers reported that most of their fellow farmers (80 %) are highly interested in the adoption of the technology. However, they proposed to increase the subsidy for adoption from 70 % to 80 %. Drip irrigation is declared a future lifeline for Pakistan's irrigated agriculture [7]. However, they stated that high initial costs and lack of awareness hamper the adoption of this technology. In the case of low head drip irrigation in Balochistan, adopter farmers reported that the technology is very beneficial and most of their fellow farmers (80 %) are taking a medium level of interest in up-taking the technology in the province. Half of the adopter farmers reported access to services of one ASP each for installation and repair and maintenance of the drip systems at their farms.

Thus, the numbers of ASPs in the study area are insufficient to meet farmers' demand for services. The results are in line with [16], they reported low adoption of the technology due to lack of awareness in farmers, incapability of ASPs to serve farmers, small landholdings, the poor resource base of the farmers, and social/cultural non-acceptance. Sample farmers reported that the adoption of the technology is not being promoted by public sector development projects. However, half of them (50 %) reported that few NGOs are making efforts to promote the technology in the study area.

Area allocation to drip irrigation system by types of fruit or vegetables is given in Table 5. It ranged from the lowest of 1.0 acre for okra/ squash-gourd in Sindh province to 1.25 for cucumber/ bitter-gourd in Punjab province. Adopter farmers of high-head HEIS of Sindh province reported that they can double the area under drip irrigation for vegetables if the subsidy program by the local LSO continues to support them in adoption. In the case of fruit crops, areas under HEIS ranged from 1.14 acres in Khyber Pakhtunkhwa province to a maximum of 8.9 acres in Punjab.

Cost-benefit analysis of low head drip irrigation by fruit types and provinces is given in Table 6. The analysis has been summed up at the country level in Figure 1. It is found that water pump installation and construction of raised tank/ storage reservoir, and land cost/rent are the main cost item in the production of fruits through the adoption of HEIS (each shares 22 % of the total annual cost of production each). Irrigation cost is the second major cost item and shares 18 percent of the total cost. Drip material and HEIS installation cost is the third main cost item with a share in the total cost of production of 11 percent. Water pump installation cost varies greatly across provinces, as it depends on bore depth and topographic/ geographic conditions. It ranged from Rs. 185,000 to Rs. 1,205,000 (Table 6). It was the lowest in Punjab province followed by Khyber Pakhtunkhwa province, with the highest in Balochistan province. Land preparation, planting material and planting cost-shared eight percent of the total cost of production. Fixed cost for fruit production through a low-head drip system was the lowest in Punjab province for mixed fruit orchards (Rs. 18,490) and was the highest in Balochistan province for grape orchards (Rs. 68,592).

The total cost of production/acre was the lowest for mixed fruit orchards in rain-fed Punjab province (Rs.74,460) and was the highest for dates and lemon orchards in Khyber Pakhtunkhwa province (Rs. 154,799). Gross revenues ranged from Rs. 69,590, for mixed fruit orchards in Balochistan to Rs. 254,373 for grapes orchards in Punjab province. Similarly, net revenue was the highest for grapes orchards in Punjab province (Rs. 106,696), with the lowest for grapes orchards in Balochistan (Rs. 41,330). The benefit-cost ratio was the highest for grapes orchards in Punjab i.e. 1.73: 1.00, followed by grapes orchards in Balochistan, date and lemon orchards in Khyber Pakhtunkhwa. While farmers having mixed fruit orchards with low-head drip installation in Balochistan faced a loss of Rs. 20,054 per acre due to low harvest prices.

Cost-benefit analyses of high-head drip irrigation systems used for the production of grapes in rain-fed Punjab and selected vegetables produced through tunnel farming in rain-fed Punjab and open fields in Sindh are given in Table 7. Share of cost items for high-head drip irrigation systems used in grapes orchards in rain-fed Punjab are presented in Figure 2. Drip material and installation and land preparation, planting material, and planting

Table 5. Area allocation to drip irrigation system by orchard/ vegetable types

Type of System	Province	Orchard/ Vegetable Type	Mean Area (acre)		
			Mini-mum	Maxi-mum	Mean
Low-head for high value orchards (Rain-fed)	Khyber Pakhtunkhwa (n=10)	Dates & Lemon	0.50	1.50	1.14
	Punjab (n=20)	Grapes	1.00	9.00	4.69
		Mixed Fruit	5.25	12.50	8.90
	Balochistan (n=20)	Grapes	1.25	19.0	7.17
		Mixed Fruit	1.00	4.00	2.22
High-head for orchards and vegetables (Rain-fed)	Punjab (n=40)	Grapes (30)	1.00	5.00	3.00
		Cucumber / Bitter-Gourd (10)	1.00	2.00	1.25
High-head for vegetables (Irrigated)	Sindh (n=10)	Okra / Squash-Gourd	1.00	1.00	1.00

are major cost items, shared 29 % each in the total annual cost of production farmyard manure & fertilizers and irrigation are other main cost items with shares in the total cost of production of 15 and 12 % respectively. Share of cost items for a high-head drip irrigation system for vegetable production in tunnels in rain-fed Punjab are given in Figure 3. Drip material and installation, and labor are major cost items and shared 32 and 15 % in the cost of production of vegetables (cucumber and bitter-gourd). Plastic tunnel cost is the third major cost item of the vegetables with a share of 11 percent. Similarly, marketing costs constitute 9 % of the total cost of production in vegetable tunnel farming. Share of cost items for a high-head drip irrigation system for vegetable production in open fields in irrigated Sindh are presented in Figure 4. Land cost/ rent, and drip material & installation costs are major cost items, shared 30 % and 27 % in the total cost of production, respectively. Irrigation, and farmyard manure & fertilizers costs shared 14 % and 8 % of the total cost, respectively. While others cost types can be considered as minor items with a share in the total cost of production of seven percent or less. In a high-head drip irrigation system, the total cost of production per acre was the lowest for okra production in open fields in irrigated Sindh (Rs. 73,243), with the highest for cucumber production in tunnels in rain-fed Punjab (Rs. 165,453). Gross revenues per acre ranged from Rs. 89,100 for okra production in Sindh to Rs. 246,160 for bitter-gourd produced in tunnels in rain-fed Punjab.

While, net revenue was the highest for grapes in rain-fed Punjab (Rs. 148,563 per acre), followed by squash-gourd produced in the open field in irrigated Sindh, and bitter-gourd in rain-fed Punjab. Farmers producing cucumber in tunnels had to bear a loss of Rs. 8,753 per acre due to the high cost of

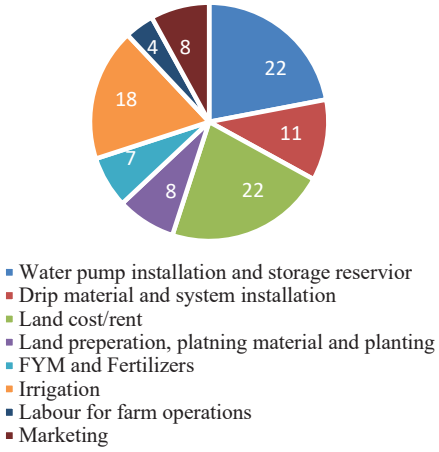

Fig. 1. Cost shares for fruit low-head drip irrigation (%)

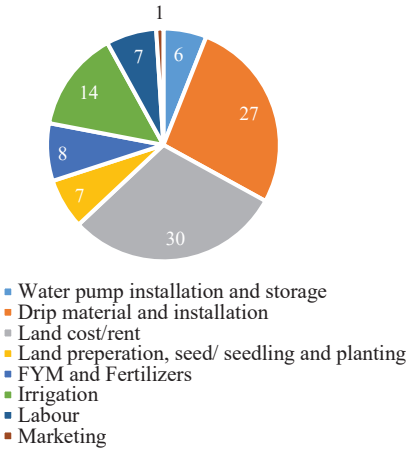

Fig. 2. Cost shares for high-head grape orchards (%)

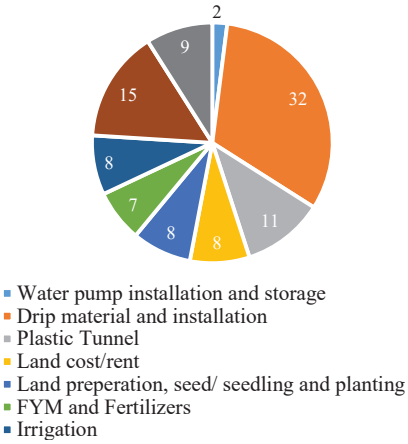

Fig. 3. Cost shares for vegetables tunnels in rain-fed Punjab (%)

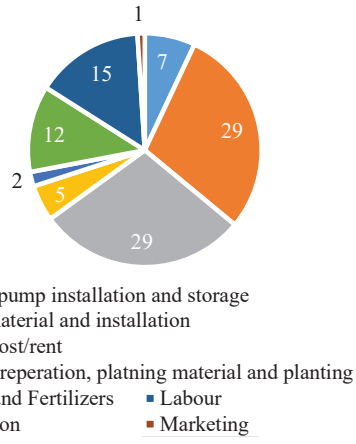

Fig. 4. Cost shares for high-head irrigation for vegetables in open fields in Sindh (%)

Table 6. Cost-benefit analysis of low-head drip Irrigation (Rs. per acre)

Costs Items with specification	Units	Quantity Range	Cost per farm/ Price Range	Life Range (year)	Value per annum				
					Khyber Pakhtun-khwaDates & Lemon	Punjab		Balochistan	
						Grapes	Mixed Fruit	Grapes	Mixed Fruit
Fixed Cost					37248	38118	18490	68592	52338
Raised tank/ reservoir (Concrete)	No.	1	65300-350000	20-25	2605	2500	1966	1395	4505
Water Pump (Peter Engine / Sub-immersive)	Rs..	-	185000-1205000	20-30	23754	8000	4757	40418	39351
Installation									
Conveying Pipes (PVC 2")	Foot	58-2285	95-170	20	432	530	226	1705	1687
Sub main (PVC 1.5"/2.0")	Foot	119-641	34-71	10-20	1238	1817	4106	4720	941
Drip lines (Other 0.75")	Meter	200-1200	7-70	10	3684	170	840	658	1058
Drippers	No.	97-633	9-20	4-10	658	813	593	194	483
Filter	No.	1	8000-20667	10	-	2067	800	-	-
Valves	No.	1-2	1700-28333	10-20	283	557	1000	1417	1600
Supporting pillars	No.	200-250	300	7	-	8526	-	10714	-
Installation cost	Rs.	-	26315	10	3000	3305	3652	2521	2278
Suckers (Dates)	No.	54	650	25	1414	-	-	-	-
Plants (Lemon)	No.	18	250	25	180	-	-	-	-
Plants (Grapes)	No.	420-485	100	10-20	-	9833	-	4850	-
Plants (Mixed Fruits)		87-110	100	20	-	-	550	-	435
Variable Cost					117551	109259	55970	58718	37306
Land Cost/ Rent	acre	1	10927	1	23684	26358	26358	27000	27000
Land Preparation	Rs.	1	8772	1	8772	6631	3652	2200	1051
Labour (Planting)	M. days	1.8-4.8	400-700	1	1930	2300	2760	2668	1022
FYM (Basal dose)	Trolley/ Trucks	1.1-3.6	2250-4350	20-25	313	405	2520	-	-
FYM (Top dressing)	Trolley/ Trucks	2.6	4350	1	11310	-	-	-	-
Gypsum	Bags	1.8	200	1	-	360	-	-	-
Fertilizer 1 (Urea)	Bags	0.78-2.42	1300-1725	1	1488	2769	1287	4175	
Fertilizer 2 (DAP)	Bags	0.85-2.42	2700-3400	1	2856	2720	2700	7260	
Fertilizer 3 (SP)	Bags	0.73	3000	1	-	-	2190	-	-
Fuel (Diesel)/ Elect. Bill (Rs.)	Liter	101-475	105	1	41475	49875	10605	1620	1623
Labour (Interculture, pruning & pollination & fruit picking	M. days	2.76-26.00	400-600	1	10386	3875	2550	2526	2316
Marketing cost	Rs.	1	15337	1	15337	13966	1348	11269	4294
Total Cost					**154799**	**147377**	**74460**	**127310**	**89644**
Production and Revenue									
Dates					159880	-	-	-	-
Consumed	Rs./kg	35	200	1	7000	-	-	-	-
Output-sold	Rs./kg	1274	120	1	152880	-	-	-	-
Lemon					36667	-	-	-	-
Consumed	Rs./kg	18	100	1	1800	-	-	-	-
Output-sold	Rs./kg	498	70	1	34867	-	-	-	-
Grapes					-	254373	-	168640	-
Consumed	Rs./kg	63-79	70-127	1	-	10033	-	4410	-
Output-sold	Rs./kg	2572-2986	55-95	1	-	244340	-	164230	-
Mixed Fruits					-	-	92425	-	69590
Consumed	Rs./kg	135-166	110-135	1	-	-	18225	-	18260
Output-sold	Rs./kg	742-870	59-100	1	-	-	74200	-	51330
Gross Revenue					**196547**	**254373**	**92425**	**168640**	**69590**
Net Revenue					**41748**	**106996**	**17965**	**41330**	**-20054**
Benefit-cost ratio (Gross Revenue/ Total Cost)					**1.27**	**1.73**	**1.24**	**1.32**	**0.78**

Source: Field Survey 2018, Pakistan

Note: Marketing cost includes Load/ unloading, transportation and commission)

Table 7. Cost-benefit analysis of high-head drip irrigation (Rs. per acre)

Costs Items with specification	Units	Quantity Range	Cost per farm or Price Range	Life Range (yrs.)	Value per annum				
					Punjab Grapes	Punjab Cucum-ber	Punjab Bitter-gourd	Sindh Okra	Sindh Squash-gourd
Fixed cost					34392	81059	81059	20370	35106
Storage reservoir (Concrete)	No.	1	100000-120000	20	1667	-	-	-	-
Water Pump (Peter Engine / Sub-immersive) Installation	No.	1	105000-281400	5-20	5000	4167	4167	5400	5400
Conveying Pipes (PVC 2"/ Galvanized steel 3"/Copper2")	Foot	220-371	70-550	10-20	3850	991	991	2000	20387
Sub main (PVC 0.5"/1.0"/2.25")	Foot	41-384	42-70	10-20	258	1792	1792	770	319
Drip lines (PVC 0.25"/0.5")	Meter	800-2943	25-70	10	3360	7358	7358	8400	4000
Drippers	No.	1067-3885	30-40	5-10	6097	23210	23210	1200	1333
Filter	No.	1	45000-50000	10	4500	20235	20235	-	-
Valves/Ventury	No.	1-4	6250-15000	10	625	948	948	600	667
Supporting pillars	No.	133	400	7	5700	-	-	-	-
Plastic tunnels cost	Rs.	1	20334	1	-	20334	20334	-	-
Installation cost	Rs.	1	15000-25000	10	2000	2024	2024	3000	3000
Plants (Grapes)	No.	267	100	20	1335	-	-	-	-
Variable Cost					57487	84394	82768	52873	56831
Seed/ Seedling cost	Rs.	1	2100-8130	1	-	8130	6504	2750	2100
Land Cost/ Rent	Rs.	1	27000	0.5-1	27000	13500	13500	24423	24423
Land Preparation	Rs.	1	3000	1	3000	4065	4065	2200	2200
Labour (Planting)	M. days	5-14	200-600	20	420	3252	3252	1000	1000
FYM (Basal dose)	Trolley	0.4	7000	1	-	2800	2800	-	-
Fertilizer 1 (Urea)	Bag	1-3	1400-1650	1	1650	1650	1650	2800	4200
Fertilizer 2 (DAP)	Bag	0.3-0.4	2800-3300	1	-	1320	1320	-	924
Fertilizer 3 (SP)	Bag	2.5	2850	1	-	7125	7125	-	-
Fertilizer 4 (Nitrophos)	Bag	0.66-1.5	2400	1	-	-	-	3600	1584
Fuel (Diesel)/ Elect. Bill (Rs.)	Liter	100-125	105	1	10815	13125	13125	10500	12600
Labor (Interculture, pruning & pollination)	M. days	2.67-25	550- 600	1	1602	3339	3339	3000	5000
Labor (Fruit picking)	M. days	8-20	550-600	1	12000	9900	9900	1600	1800
Marketing cost	Rs.	1	1000-16188	1	1000	16188	16188	1000	1000
Total Cost					**91879**	**165453**	**163827**	**73243**	**91937**
Production and Revenue									
Grapes					240460	-	-	-	-
Consumed	Kg.	100	123	1	12300	-	-	-	-
Output-sold	Kg.	2480	92	1	228160	-	-	-	-
Cucumber					-	156700	-		
Consumed	Kg.	320	40	1	-	12800	-	-	-
Output-sold	Kg.	5756	25	1	-	143900	-	-	-
Bitter-gourd					-	-	246160		
Consumed	Kg.	352	60	1	-	-	21120	-	-
Output-sold	Kg.	5626	40	1	-	-	225040	-	-
Okra					-	-	-	89100	-
Consumed	Kg.	40	30	1	-	-	-	1200	-
Output-sold	Kg.	5860	15	1	-	-	-	87900	-
Squash-gourd					-	-	-	-	199600
Consumed	Kg.	40	40	1	-	-	-	-	1600
Output-sold	Kg.	9900	20	1	-	-	-	-	198000
Gross Revenue					**240460**	**156700**	**246160**	**89100**	**199600**
Net Revenue					**148563**	**-8753**	**82333**	**15857**	**107663**
Benefit-cost ratio (Gross Revenue/ Total Cost)					**2.62**	**0.95**	**1.50**	**1.22**	**2.17**

Source: Field Survey 2018, Pakistan Note: Marketing cost includes Load/ unloading, transportation and commission)

production and low output prices. The benefit-cost ratio was the highest for grapes produced in rain-fed Punjab (2.62:1.00), followed by squash-gourd in Sindh (2.17:1.00) bitter-gourd in rain-fed Punjab (1.50:1.00) and okra in Sindh (1.22:1.00). The results are in line with [17] as they declared that drip irrigation has a greater scope for the production of seasonal as well as off-season vegetables, especially in water-scarce areas of Pakistan. Similarly, drip irrigation was recommended for areas with marginal to poor quality groundwater to obtain high crop production and water use efficiency [18].

4. CONCLUSION AND RECOMMENDATIONS

Drip irrigation is a promising water-saving technology. It is being admired by the farmers predominantly in rain-fed areas of the country. However, the high initial cost is reported as the main constraint in its adoption. Moreover, the limited availability of materials and services required for the installation of the drip irrigation systems, and to keep these systems in an operational state also hamper wide-scale adoption of the technology. Farmers in far-flung areas of Khyber Pakhtunkhwa, Sindh, and Balochistan with tough terrain are resource-poor, and cannot afford to adopt the technology on their own. On-Farm Water Management is promoting the technology by providing technical support and subsidy to farmers in Punjab province. However, farmers were concerned about the quality of the materials, and the estimation of installation cost by the companies contracted by the department for the installation of the systems. Farmers still consider it a little complex technology to adopt, operate and maintain. It is required to build their confidence in the usefulness of the technology, awareness events for potential adopter farmers, and training sessions for local technical staff and plumbers should be organized. This will create demand for materials and services, as well as help, improve the supply of materials, and repair & maintenance services at the local level. Farmers' capacity may also be built for minor trouble shootings in drip irrigation systems. In irrigated areas of the country, farmers are used to flooding irrigation of field crops. Thus, they still consider that drip irrigation systems do not fulfill the water requirement of the crops and result in weak/ stunted root growth hence low productivity. Wide-scale demonstration of the technology, as well as research, is required to convince farmers that drip irrigation has a clear advantage over traditional flood irrigation systems. Farmers should also be persuaded that they can reduce the installation, and operational cost of HIES, and ultimately crop production costs either through proper utilization of high-efficiency irrigation systems or area expansion under these systems at their farms. Similarly, policy formulators and development institutions/ agencies should carefully consider crop zoning in devising their plans for the promotion of technology in the country.

5. ACKNOWLEDGEMENTS

This study has been conducted with the technical and financial support of USDA under the project "Water Dialogue-Diffusion and adoption through partnership and action of the best watershed rehabilitation and irrigation practices and technologies to help rural farmers". The authors are also highly grateful to the project implementing agency ICARDA-Pakistan for the technical support furnished to conduct this study. Technical contributions of ICARDA Head Quarters, Lebanon, and Regional Office, Jordan are also very much appreciated. In this reference, the guidance of Dr. Aden Aw-Hassan, Consultative Group on International Agricultural Research (CGIAR) in the training of the survey team and designing of survey tools is much acknowledged. Moreover, facilitation provided by technical partners/ development institutions viz. CEWRI, PARC-NARC; NRSP; PCRWR; SAWCRI, RDF, and MUET in sampling of the adopters, and conducting field surveys all over the country are highly commendable

6. CONFLICT OF INTEREST

There is no conflict of interest among the authors of the article.

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