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IMPROVING WATER PRODUCTIVITY BY ADOPTION OF HIGH EFFICIENCY IRRIGATION SYSTEMS AMONG VEGETABLE GROWERS IN DISTRICT RAWALPINDI, PUNJAB PAKISTAN

Muhammad Bilal and Syed M. Zakria*

Institute of Agricultural Sciences, University of the Punjab, Lahore, Pakistan
***Corresponding author's e-mail: smzakria1@yahoo.com**

Pakistan is facing challenges of poor land and water productivity, depletion of ground water, water scarcity, food security and environmental implications due to obsolete and inefficient irrigation, agriculture practices. To mitigate impending crisis the only way out is to opt holistic approach focusing on better management of resources, incentives for farmers to be more efficient user. The future is all about adoption of the most efficient water saving interventions for improving conveyance, application, and water use efficiencies. It is obligatory to conduct research for ascertaining the impact of modern irrigation practices on the performance of different crops. Thus, district Rawalpindi, Punjab Pakistan was selected for research purposes to determine water productivity improvement along with other objectives by adoption of HEISs amongst vegetable growers. The present article covers one of the objectives, the improvement in water productivity. Data of 135 acres were collected; 108 acres, 4 acres from each 27 sites under DIS and 27 acres, 1 acre adjacent to site as control irrigated with conventional method. It is concluded that by adoption of DIS significant results have been achieved in terms of crop diversification trend. Considering unit of 1 acre irrigation time saving 43.80 minutes, volume saving 1223.93 m^3 leading towards yield increasing by 32618.5 kg income increasing and the ultimate objective enhancing water productivity up to 15.55 kg/m^3 estimated also. 100% respondents observed substantial yield increase, with DIS 71% found very easy, 80.7% stated difficult with conventional irrigation method. 89.63% users desired to have procedural change in existing project. Several changes were proposed from capacity building to backup services and the most crucial 55% desired to change subsidy ratio 40-60% with 10-90% shared by beneficiaries and by government, respectively. At the end farming community placed DIS at the summit as the most efficient water saving initiative having multiple advantages.
Keywords: drip irrigation system, environmental implications, food security, water productivity, subsidy ratio.

INTRODUCTION

Pakistan is agriculture dominant country having total population 207.77 million with segregation of 63.62% living in rural and 36.38% in urban areas. The country comprises of total geographical area 79.71 million hectares while Punjab owns 20.63 million hectares out of which cropped area of the province is 17.03 million hectares (Govt. of Pakistan, 2020). Agriculture holds leading position by contributing 19.3% in national gross domestic product (GDP) and providing 42.3% labour force also (Govt. of Pakistan, 2020). Pakistan is lucky enough to have one of the largest gravity flow irrigation system known as Indus Basin Water System (IBWS). In spite of having such marvellous system, due to sedimentation, the storage capacity is depleted and on the other hand efficiency of more than century old deteriorated system has been dropped up to 40-60%. Consequently, facing severe water shortage and canal withdrawal observed -19% in 2017-18 (Govt. of Pakistan, 2018). It is further added that northern tract of Punjab being rain fed is heavily dependent for augmentation and surface irrigation on ground water extraction.

Before moving on water productivity and water use efficiency status of Punjab Pakistan, better to keep along the aspect that agriculture sector claims major use of fresh water on the globe soaking up to 70%, industrial uses consume 22% along with other sectors such as municipal, power generation and commercial institutes. Demand is keep on growing further draining resources from river to underground aquifers having significant impact on global water scarcity. Hence intersection water scarcity, food security and climate change, considering the impending crisis need to be addressed urgently. Pakistan's 81% cropped area is irrigated and 90% of outcomes are from irrigated land. In spite of occupying crucial significance, land and water productivity is far behind the sustainable level even when compared with the neighbouring countries. In-adequate supplies of irrigation water coupled with inefficient irrigation, agriculture practices having 40% performance at farm level are major obstacles resulting in poor land and water productivity, depletion of ground water, water scarcity, food security and climate change on top of it (Akram *et al.*, 2020; Awais *et al.*, 2020). The only way out is adoption of holistic approach focusing at more efficient management of resources, growing crops suitable to local climate and incentives for farmers to be more efficient user (Brodt *et al.*, 2011).

One of the most efficient irrigation methods is drip irrigation system Chomsang *et al.* (2021). Regular periodical maintenance to run the systems smoothly and capacity building are crucial for adoption of water saving interventions. Drip and sprinkler irrigation systems are commonly known as HEISs Biswas *et al.* (2015). Drip irrigation is also known as trickle or micro irrigation system. DIS is the most efficient initiative for application of water, fertilizer and nutrients required for plants at various growth stages. The water is applied slowly, regularly and frequently to effective root zone of the plants through emitters laid down above or below the surface in the field designed for the particular crop to enhance water productivity. Drip system is inclusive of pumping unit, fertilizer tank, connecting fittings, filters, and underground main pipelines with field hydrants, header pipes, laterals and emitters Shabbir *et al.* (2020).

The present study was carried out to determine the impact on water productivity along with the other objectives by adoption of HEISs among vegetable growers in district Rawalpindi, Punjab Pakistan. Government of the Punjab during the year 2012-13 (initially for five years then extended for another four years till 2020-21) has launched the HEISs under the title "Punjab Irrigated-Agriculture Productivity Improvement Project" (PIPIP) with the total cost Rs. 67,459.00 million on cost sharing basis Rs. 41,737.95 million by the government and Rs. 25,721.04 million will be contributed by the beneficiaries Department of Agriculture (2017). The key objective of the mega project along with others is improving irrigation water productivity by adoption of HEISs initiatives and capacity building of stake holders in better management of land and water resources. The research would help all stake holders to initiate corrective measures at the most appropriate time by avoiding detrimental elements. And on other hand would fill in the vacuum of non-availability of the data/literature in the country at government and educational institution levels pertaining to recently introduced irrigation water savings initiatives.

MATERIALS AND METHODS

The district Rawalpindi is located at an elevation of 508 meter above sea-level in the northern most part of Punjab province comprising upon total area of 526000 hectares out of which crop area is 273000 hectares. The district has population of 5.406 million as 4th largest city of Pakistan with literacy rate 74%. The district is selected for study because of possessing reasonable number of HEISs scheme installed for vegetable cultivation. The district consists of 7 tehsils; Murree, Kotli Sattian, Kahuta, Kalar Syedan, Gujjar khan, Taxila and Rawalpindi. Murree and Kotli Sattian do not possess HEISs installed vegetables site. The rest, entire district is covered having total 27 sites adopted DIS for vegetables cultivation. The present research is participatory in mode focusing at one of the objectives along with others determining impacts of HEISs adoption on water productivity. Data of 135 acres were collected, 108 acres, 4 acres from each 27 sites under DIS and 27 acres, 1 acre adjacent to DIS as control irrigated conventionally. Authenticated complete lists were obtained from on-farm water management district office. The data pertains to year ending December 2018, collected from field personally at the doorstep of the beneficiaries, through pretested questionnaire. Triangulation approach was used to figure out water productivity. The objectives of research were taken as dependent variables. Independent variables such as education level, irrigation source, socio-economic conditions, capacity building was assessed to reach at the conclusion. Quantitative data were analysed using statistical package for social sciences (SPSS). Descriptive or univariate analysis for frequencies, percentages, means, standard deviations and bi-variant analysis for establishing relationship between two variables were taken into consideration. Student's t-Test was applied to test diagrammatic interpretations observing association between dependent and independent variables.

RESULTS AND DISCUSSIONS

***Education*:** The data revealed that lowest level in adoption of drip irrigation system is primary level of education, then comes intermediate, 3rd position is with matric and highest percentage almost half possess graduation level education. Percentages were remained as; 3.7%, 18.5%, 26.7% and 51.1% respectively Fig. 1. Hassan *et al.* (2002) also found significant relationship of age and education of the respondents with the adoption of improved production technologies.

***Land Holding and Income*:** It is claimed by the M&E Consultants (2018) that HEISs adopters are relatively wealthy, average farm size of vegetable growers is higher (5.48 acres) in district Rawalpindi (as assessed in the research) whereas Punjab average is 2.1 acres. Similarly, at 27 sites DIS owners, 100% availed the tunnel technique and 7.4% of them availed solar powered system as source of energy too under "Agri. Kissan Package" by the Punjab agriculture department through on-farm water management. Therefore, it is also concluded that DIS owners possess higher education, wealthy and higher awareness level. Shaik *et al.* (2015) concluded that education and farm size had positive association with adoption of farm practices.

It is determined during study and reflected in Table 1; 100% area inclusive of DIS and control under conventional irrigation system vegetables have grown under tunnel and 100% were seasonal type tunnels. Moreover, 82.2% area was covered through walk in tunnel except 17.8% under high tunnel. The prime reason was subsidy provision under ongoing HEISs as a component of PIPIP project. It is indicative of fact farmers are motivated and convinced to adopt HEISs initiatives to enhance land and water productivity which is in line with the assessment of M&E Consultant (2018).

Table 1. Distribution of respondents regarding cultivation of vegetables by tunnel farming.

		Count	N %
Use tunnel farming	Yes	135	100.0%
	No	0	0.0%
Tunnel type	Yes Seasonal	135	100.0%
	No Off Season	0	0.0%
Kind of tunnel type	Low Tunnel	0	0.0%
	Walk in Tunnel	111	82.2%
	High Tunnel	24	17.8%

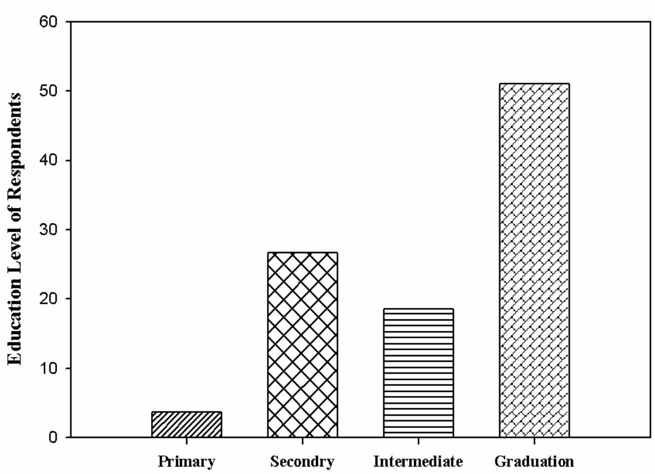

Figure 1. Reflecting the percentage of education level of respondents.

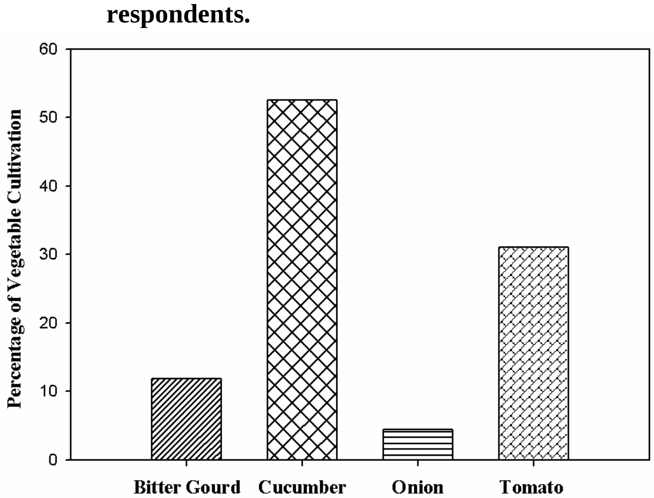

Figure 2. Detail of Vegetable Cultivation under Tunnel Technique and Drip Irrigation System

***Vegetables cultivations under drip irrigation system*:** The Fig. 2 reveals the detail of vegetables cultivated under tunnel and under DIS of the area 135 acres as studied during the research. The obtained percentages were remained as; 52.59% cucumber, 31.11% tomato, 11.85% bitter gourd and lowest 4.44% onion cultivation. The shift towards more profitable crop is visible instead of routine crops pattern. These results are similar to M&E Consultant (2018) estimation, Mahmood *et al.* (2012), FAO (2003) they also expected the change in cropping pattern for enhancing water productivity by adoption of improved agriculture practices.

***Adoption of DIS as HEISs*:** The results given in Fig. 3 determined that 100% respondents/vegetable growers opted to go for DIS in adoption of HEISs considering the most efficient irrigation method due to multiple advantages. Likewise, Barta *et al.* (2004) ranked DIS, as the most efficient water saving intervention introduced so far.

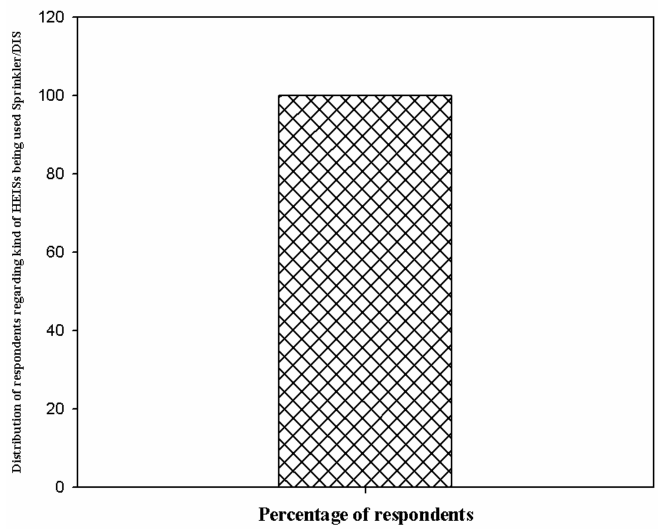

Figure 3. Distribution of respondents regarding kind of HEISs being used sprinkler/DIS

***Comparison of DIS and conventional irrigation methods*:** Comparison of DIS and conventional irrigation methods pertaining to irrigation frequency (Nos.), depth of water applied (inches), volume of water applied (m^3) and time taken (minutes) for irrigation of 1 acre are analysed in Table 2.

Results of analysis concluded that DIS irrigation frequency (HOW MANY TIMES) comparing with conventional system is significantly higher with t value 43.12 and p value < 0.000, frequency in case of DIS was 133.70 while 35.21 times in conventional method with difference of means 98.50 Nos. In DIS controlled amount of water is applied to the plant root zone, slowly, regularly and frequently through tubes by emitters Kooji *et al.* (2013). Average means of depth estimated in inches (HOW MUCH DEPTH) in case of DIS remained 4.8 and in conventional method 5.00 depth inches applied with difference of means -0.13 (with t value -4.00 and p value 0.000) highly significant too.

Result of quantity of irrigation water applied (m^3), (HOW MUCH QUANTITY), volume applied in case of DIS 2671.52

Table 2. Comparison between HEISs method and Conventional method regarding water irrigation frequency, average depth, water quantity, time for irrigation/acre .

Statement	Descriptive statistics				Relationship		Difference			t	P
	Mean	N	SD	SE	r	P-value	Mean	SD	SE	value	value
Q16ia Water irrigation frequency – HEIS (Nos.)	133.70	135	20.96	1.80	-0.284	0.001	98.50	26.54	2.28	43.12**	0.000
Q16ib Water irrigation frequency – Conv. (Nos.)	35.21	135	11.38	0.98							
Q16iia Average depth – HEIS (in)	4.87	135	0.59	0.05	0.929	0.000	-0.13	0.38	0.03	-4.00**	0.000
Q16iib Average depth – Conv. (in)	5.00	135	0.86	0.07							
Q16iiia Water quantity – HEIS (volume m^3)	2671.52	135	786.49	67.69	0.963	0.000	-1223.93	370.33	31.87	-38.40**	0.000
Q16iiib Water quantity – Conv. (volume m^3)	3895.46	135	1061.66	91.37							
Q16iva Time for irrigation/acr – HEIS (minutes)	53.79	135	30.41	2.62	0.829	0.000	-43.80	23.18	2.00	-21.95**	0.000
Q16ivb Time for irrigation/acr – Conv. (minutes)	97.59	135	40.93	3.52							

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01); r = Pearson's correlation; SD = Standard deviation; SE = Standard error

Table 3. Comparison between HEISs method and Conventional method regarding vegetable production.

Statement	Descriptive statistics				Relationship		Difference			t	P
	Mean	N	SD	SE	R	P-value	Mean	SD	SE	Value	Value
Vegetable production – HEIS kg	54911.1	135	15416.3	1326.8	0.933**	0.000	32618.5	9255.7	796.6	40.95**	0.000
Vegetable production – Conv. kg	22292.6	135	6968.3	599.7							

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01) r = Pearson's correlation, SD = Standard deviation, SE = Standard error

Table 4. Comparison between HEISs method and Conventional method regarding increase in water productivity.

Statement	Descriptive statistics				Relationship		Difference			t	P
	Mean	N	SD	SE	r	P-value	Mean	SD	SE	Value	Value
Water productivity increase – HEIS kg/m^3	21.55	135	7.65	0.66	0.736	0.000	15.55	6.47	0.56	27.90**	0.000
Water productivity increase – Conv. kg/m^3	6.00	135	1.75	0.15							

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01), r = Pearson's correlation, SD = Standard deviation, SE = Standard error

m^3 whereas in conventional method is 3895.46 m^3 highly significant difference (t value -38.40 and p value 0.000) with difference of means -1223.93 m^3 proving the DIS the most efficient and most effective method saving 35-65% irrigation water Martínez and Reca Reilly (2014). Similar conclusion has been drawn by the IFC (2014), that 30-60% of water use efficiency is increased. Further concluded the time (minutes) saving to irrigate 1 acre vegetable sown (HOW MUCH TIME) both DIS and control with conventional methods. The mean times of DIS are 53.79 minutes followed by 97.59 minutes conventional method difference of means -43.80 with t value -21.95 and p value 0.000 highly significant result saving water, time, resultantly labour and energy cost with various other multiple advantages. Kumar *et al.* (2008) evaluated the water use efficiency through DIS would lead to reduce over exploitation of ground water also. Robert (2008) termed DIS the most befitting solution for water saving up to 45% more in comparison of other water saving technique such as sprinkler.

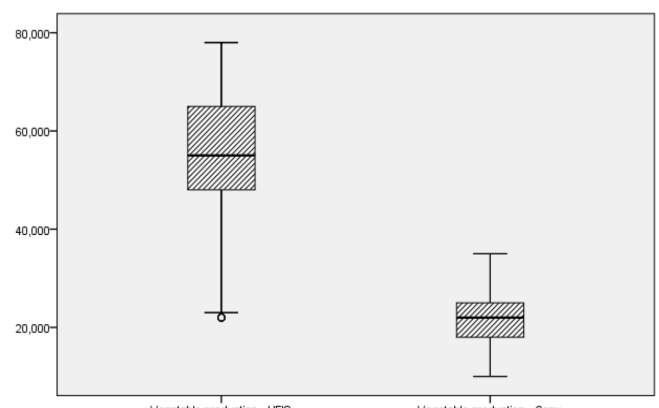

Figure 4. Comparison of vegetable production amongst DIS and vegetable cultivation under control in kg/acre.

***Comparison of vegetables production/yield (kg/acre)*:** Analysis of data collected regarding vegetable grown under

DIS and control irrigated conventionally given in Table 3 reveals that means for HEISs production is 54,911.1 kg and for control yield remained 22,292.6 kg which is highly significant with values t 40.95, p 0.000. Results enhancing yield with irrigation water saving interventions are similar to studies conducted by different researchers narrating, with adoption of water saving technology increased area and yield by 20% and 15% Mahmood *et al.* (2012), Chattha *et al.* (2017).

Comparison of water productivity: DIS vs Conventional methods**:** The means of water productivity estimated in Table 4 with DIS is 21.55 and with control/conventional irrigation method is 6.00 differences of mean is 15.55 kg/m^3 (t value 27.90 and p value 0.000) which was highly significant. Increasing water productivity is the ultimate goal of every-water saving initiatives which is quite handsome incentive in this particular case study for beneficiaries in terms of water use efficiency, socio-economic status, sustainable environment and sustainable agriculture. Similar results are assessed reflecting through adoption of DIS increase in crop productivity 30-40% Jha *et al.* (2017).

Production/yield improvement through DIS**:** In response to question whether DIS is helpful in increasing yield. Result given in Table 5 describing absolute chunk; 100% respondents are convinced that yield is increased substantially. It is also positive indicator that 71.1% observed production increased very easy with adoption of DIS and 80.7% found difficult to increase vegetable production with existing conventional irrigation practices.

Consensus have been developed among the researchers around the globe that DIS is the most effective and efficient irrigation initiative for enhancing land and water productivity in addition to various other advantages. Similarly, Mahmood *et al.* (2012), Gunaratne *et al.* (2005) and Boyd *et al.* (2019) noted that by using interventions crop and water productivity is substantially increased.

Suggestions by the respondents**:** The vegetable growers installed drip irrigation system (DIS) in district Rawalpindi Punjab were asked to share experiences and to put forward the suggestions for improvement in the existing facility offered by the government. The responses are summarized as under before leading to the conclusion. The 89.63% beneficiaries desired to have procedural changes in ongoing OWFM Wing lead PIPIP only 10.37% very thin percentage is satisfied. Proposals were floated pertaining to capacity building training duration, training site, provision of production plan, backup services provided. But the most crucial change desired by them is to modify subsidy ratio. They suggested to enhance subsidy ratio from prevailing 40-60% to 50-50%, 20-80% and 10-90% with percentages as 4%, 41% and 55% respectively as reflected in Fig. 5. The subsidy ratio refers to cost sharing arrangement at present 40% of the system cost is contributed by the farmers and 60% is borne by the Government.

Table 5. Distribution of respondents regarding their views about increase in production by HEISs and Conventional methods

		Count	N %
HEIS helpful to improve production	Yes	135	100.0%
	No	0	0.0%
Comparison easiness crops – HEIS	Difficult	0	0.0%
	Easy	39	28.9%
	Very easy	96	71.1%
Comparison easiness crops – Conv	Difficult	109	80.7%
	Easy	26	19.3%
	Very easy	0	0.0%

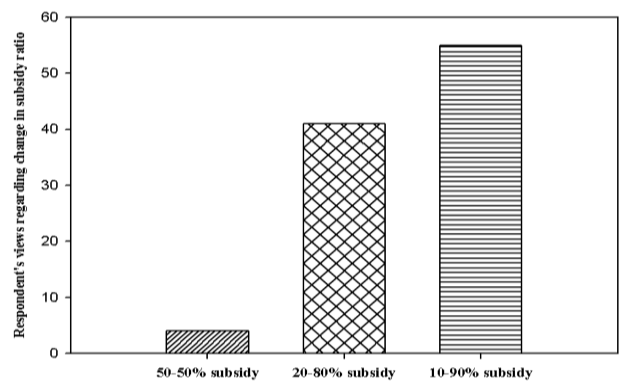

Figure 5. Respondent's views regarding change in subsidy ratio

The proposal is in line with the findings such as, for successful adoption proper identification of farmers (satisfied and enthusiastic) and subsidy programs are prerequisite Gunaratne *et al.* (2005). Madhava *et al*. (2016) have taken high initial cost and inadequate subsidy as constraint in adoption of DIS. Brodt *et al.* (2011) concluded that for adoption of DIS farmers should be offered incentives to be more efficient users.

Conclusion**:** The research concludes that education have positive significant impact on adoption of irrigation water saving initiatives. 100% beneficiaries adopted DIS considering it the most efficient coupled with 100% vegetables growing under tunnel technology and 7.4% of them availed the solar powered source of energy too. By adoption of DIS significant results have been achieved in terms of crop diversification trend. Considering unit of 1 acre irrigation water time saving 43.80 minutes, volume saving 1223.93 m^3 leading towards yield increase by 32618.5 kg income increasing and the ultimate objective enhancing water productivity 15.55 kg/m^3 also. 100% vegetable growers responded that through adoption of DIS yield is increased substantially, 71.1% found very easy and 80.7% observed difficult to increase yield with conventional irrigation methods. 89.63% respondents desired to have procedural changes in existing ongoing project. Therefore, DIS however remained at the summit as the most effective and efficient irrigation water saving intervention due to multiple advantages in general and increasing water productivity in specific.

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