International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 13, Issue 12, 2021, pp.-10986-10990.
Available online at https://bioinfopublication.org/pages/jouarchive.php?id=BPJ0000217

Research Article

ENHANCING CROP AND WATER PRODUCTIVITY OF WHEAT IN DIFFERENT ESTABLISHMENT METHODS IN HARYANA: AN ON-FARM STUDY

N. SHARMA[1], A.K. BHARDWAJ[2], P. SOMAN*[3], T. PANDIARAJ[4] AND B.K. LABH[5]
[1]Executive Engineer, Irrigation and Water Resources Division, Haryana, India
[2]Advisor, Jain Irrigation System Ltd. Jalgaon, 425001, Maharashtra, India
[3]Principal Agronomist (Global), Jain Irrigation System Ltd. Jalgaon, 425001, Maharashtra, India
[4]College of Agriculture, Azamgarh, 276001, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya, 224 229, India
[5]Vice President, Jain Irrigation System Ltd. Jalgaon, 425001, Maharashtra, India
*Corresponding Author: Email - dr.soman@jains.com

Received: December 01, 2021; Revised: December 26, 2021; Accepted: December 27, 2021; Published: December 30, 2021

Abstract: Increasing productivity of crop and water is one of the crucial requirements of farming. The aim of this study was to estimate wheat yield response to micro-irrigation under different planting methods and work out the water productivity under on farm conditions in Haryana, India. Three establishment methods consisting of conventional wheat sowing, zero tillage sowing and sowing with the happy seeder were field evaluated under three irrigation methods, conventional flood irrigation, drip irrigation and sprinkler irrigation against farmers' practice. On-farm experimental evaluation of these combinations were conducted at Gumthala Garhu village, Pehowa of Kurukshetra district, Haryana, India from 2018-19 to 2020-21 during rabi season (October-January). The study revealed that both establishment and irrigation methods did not significantly influence grain yield of wheat crop. However, conventional broadcasting and drip irrigation method had higher grain yield. Similarly, PWP and EWP for IWU and TCWU were comparatively higher in the conventional broadcasting plus drip irrigation treatment combination. In the study, drip and sprinkler irrigation methods used 2.43 and 2.01 times lower water to produce one kg grain of wheat than flood irrigation method. The WUE of conventional broadcasting plus drip irrigation method was significantly higher than the WUE in any other methods or combinations. Eventually, our findings indicate that drip irrigation can be adopted in the region to increase water productivity, water use efficiency, optimize grain yield, and minimize water loss.

Keywords: *Micro-irrigation, Water productivity, Wheat, WUE, Yield*

Citation: N. Sharma, *et al*., (2021) Enhancing Crop and Water Productivity of Wheat in different Establishment Methods in Haryana: An On-Farm Study. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 13, Issue 12, pp.- 10986-10990.

Introduction

Moisture regime is the most vital factor influencing crop growth and productivity. The growing global population is increasing the pressure on the food basket. It is projected that food demand will increase by roughly 70% by 2050 [1] which making effective water planning and management and further, about 40% of the world food supply is meet by irrigation agriculture means irrigation water is the single largest water user on the planet. The scarcity of irrigation water caused by the industry growth and urban area expansion endangers food security worldwide [2,3]. It is estimated that about two-third of the world's fresh water is being consumed for different farming activities, while the imbalance in the ratio of ground water discharge to recharge has resulted in groundwater over-utilization [4,5]. A study by the International Water Management Institute (IWMI) reported about 50% of the increase in demand for water by the year 2025 can be met by increasing the effectiveness of irrigation.

Wheat (*Triticum aestivum* L.) is the second most vital cereal crop next to rice and one of the main staple food crops of humankind. The total area of wheat in the world is 215.29 million hectares with production of 772.64 million tones and productivity is 33.90 q ha-1 annually in 2020-21. Wheat bestows significantly to the country's food security through supplying greater than 50% of the calories to the people who primarily rely on it. Currently in India, large area under wheat crop is grown under surface irrigation with 5-6 recommended flood irrigation, with very low water use efficiency of about 66.5% [6] due to large conveyance and distribution losses [7]. Thus, judicious use of irrigation frequencies for wheat crop production is very essential as it ensures better grain yield.

However, India's water resources become fragile and under severe stress mainly in the perspective of agriculture. The country upholds 16% of the world's human population and 20 % livestock population with only three percent of the world's water ([8]. Thus, it is most imperative to resourcefully manage irrigation and consumption of water while maintaining or increasing yield through technologies development [9].

Such an alarming rate of declining water resource is urging scientists and grower to choose new approaches for increasing the water productivity of wheat. Recognizing the magnitude of sustainable water use efficiency in agriculture, variety of techniques have been evaluated by scientists since the late 70s to minimize the requirement of irrigation water and improving the water productivity particularly in the use of surface irrigation water but the net benefit of these are not very remarkable.

Micro Irrigation (MI) is one of the most potent management approaches initiated in recent times to manage overutilization of water in Indian agriculture which consists of mainly drip and sprinkler irrigation method. Of them, drip irrigation is most efficient irrigation method and reported to increase yield of up to 100% and water savings of up to 40-80%. It also substantially enhances water productivity and saves associated inputs *i.e.* pesticide, fertilizer, and labor. Micro-irrigation can be followed successfully to irrigate wide range of horticultural crops particularly in vegetables, orchard crops, flowers and plantation crops but in contrast, there are limited studies conducted for field crops like wheat. It is estimated about 1000 litre of irrigation water is needed to produce one kilo gram of wheat yield grains [10].

Thus, it is possible to save 18976 million cubic-meter of water per year by adopting drip irrigation method in wheat crop in total wheat production of India. However, degree of successfulness and adoptability of micro-irrigation-irrigation may be changes with climate, soil type and irrigation management. Therefore, it has to be evaluated for region and site specific.

Only few studies have been tested for the possibility of the micro-irrigation systems (drip and sprinkler) in India for cereal crops. This study has the main concern on agronomical evaluation of micro-irrigation on wheat crop yields and water productivity under on-farm condition of Haryana, India.

Materials and Methods

Description of the study area

Three years on-farm field experiment was carried out on a farmer's field in 2018-19, 2019-20 and 2020-21 at Gumthala Garhu village, Pehowa of Kurukshetra district, Haryana, India. The research site is located at 30 ̊75'N Latitude and 76 ̊78'E Longitude and at an altitude of 260 m above sea level. The climate is prevailed sub-tropical with a hot-dry summer, wet monsoon season (late June to mid-September) and a cool-dry winter. The area receives an average annual rainfall of 720 mm but with much deviation in quantity and distribution, more than 80% of which falls between the months of July and September. However, late onset and early cessation of rains, and intermittent periodic dry-spells are general causes of fluctuation in crop production with sporadic drastic reductions in yield. The dominant soil type of the area is alluvial with sandy clay loam texture having low in organic matter, nitrogen and phosphorus and medium range in potassium.

Experimental design and treatments

The experiment was conducted in two different segment fields. Wheat crop grown in same field as rice was grown previously. This field consisting of nine acres was equally divided into three portions and each portion with three acres used for different establishment method i.e. sowing with happy seeder, zero tillage and conventional seed broadcasting. On the other hand, each three acres field was sub divided into three segments and each segment with one acre was arranged for laying drip, sprinkler and conventional flood irrigation methods. Besides, a farmer's practice with conventional wheat cultivation was included in the experiment to compare with different treatments. The data were arrayed in the factorial randomized block design experiment with three replications.

The treatments of irrigation were based on the average water requirement of wheat crop upon soil moisture condition. The drip irrigation water was supplied to the field through PVC pipe after passed through the screen filter with a 12.5 HP motor from the bore-well source. The pressure at 2.0 kg cm^{-2} was maintained in the system throughout the irrigation period. From the sub-main pipes, in-line laterals with 16 mm thickness were laid out at a spacing of 0.6 m with a 2.4 lph discharge rate and emitter position at a distance of 40 cm. In case of sprinkler irrigation system, a line source of the sprinkler irrigation system was installed in the field. The sprinkler heads were placed at 10 m intervals on the lateral pipe and the total number of sprinklers was 120 with a part cycle for a one-hectare land area. The treatment of conventional surface irrigation reflects the existing package of practices of irrigating at moisture sensitive periods. The farmers' practice plots were irrigated when soil got dried. Net plot 10 m^2 was harvested for recording yield.

Crop management

The wheat crop was grown in previously raised rice crop field. Before wheat crop in each year, there were two harrowing subsequently planking the field in conventional seed broadcast treatment. Wheat (HD 2967) was sown on second week of November in each year as per treatments at a seed rate of 100 kg/ha and 20 cm row spacing. In treatment of conventional broadcast, seed was broadcasted manually. The fertilizer NPK recommendation is 150-60-40 kg ha-1. All irrigation treatment plots were applied with a basal fertilizer (50% as urea, 100% P as SSP and 100% K as MOP) before sowing. Another 50% N as urea was broadcasted in two equal splits i.e. at CRI stage on 22 DAS and at spikelet initiation on 45 DAS. The Zero tillage and happy seeder treatment plots were sown with 200 kg NPK (12-32-16) per hectare with seed drill basally and rest as top dress and spray before flowering. Weeds in wheat field were controlled by applying a pre-emergence herbicide pendimethalin @ 1.0 l a.i. ha^{-1} next day after sowing, and a post-emergence herbicide (2,4-D @ 0.6 kg a.e. ha^{-1}) on 25 DAS. Weeds that escaped these treatments were removed manually at 45 DAS. Other management practices were followed as per the recommendation of the state agricultural department.

Observation

Grain Yield

Grain yield was determined from an area of 10 m2 in the centre of each plot, which was harvested and threshed manually and yield was expressed as kg ha^{-1} at 14% grain moisture.

Water productivity

In this study, physical water productivity was estimated by the following equation as per the methodology given by Sharma *et al*., [11].

Physical water productivity (PWP) was calculated as the ratio of agricultural output to the amount of water consumed from all available sources including irrigation, rainfall etc and expressed in (kg m^{-3}) [Eq-1&2].

$$PWP_{TCWU} = \frac{\sum_{ie\ crop} \text{Average Yield}_i}{TCWU} \times \text{Area} \qquad \text{[Eq.1]}$$

$$TCWU = \sum_{iecrop}^{n} \left(TCWU_{ki}^{IR} + TCWU_{ki}^{RF}\right) \qquad \text{[Eq.2]}$$

Irrigation water productivity or use (IWU)was estimated as ratio of the crop output to the irrigation water applied by the farmer/ irrigation system either through surface canals, tank, pond or the well and tube well during the crop growth [Eq-3].

PWP_{IWU}=[Irrigated Yield of i^{th} crop ×Area under i^{th} crop] / [Irrigation water applied per unit area of i^{th} crop × Irrigated area under i^{th} crop [Eq-3]

Like PWP, The Economic Water Productivity (EWP) was also calculated in two approaches. EWP was estimated as the ratio of value of crop output to the amount of water consumed [Eq-4] or to the amount of irrigation water applied by the farmer (Eq. 5) and expressed as (Rs m^3).

EWP_{TCWU}= [(Average Yield of i^{th} crop × Area under i^{th} crop × Farm Harvest Price of i^{th} crop per unit quantity of crop output] / [TCWU of the i^{th} crop] [Eq.4]

EWP_{IWU}= [Irrigated Yield of i^{th} crop × Area under i^{th} crop × Farm Harvest Price of i^{th} crop per unit quantity of crop output] / [Irrigation water applied per unit area of i^{th} crop × Irrigated area under i^{th} crop output] [Eq.5]

In the above equations, $\sum_{iecrop}$ Average Yield is the average yield of i^{th} crop *i.e.* wheat. TCWU is the total consumptive water use. IR and RF means irrigated and rainfall, respectively. $TCWU_{ki}^{IR}$ and $TCWU_{ki}^{RF}$, respectively represent irrigated and rainfall water used of i^{th} crop in kth season. The farm harvest price of crop used in this study based on minimum supporting price as per the recommendation of government of India in the respective year. The price of wheat for the period of 2018-19, 2019-20 and 2020-2021 were INR. 18.40, 19.25 and 19.75 per kg grain of wheat, respectively.

Statistical analysis

All three years data were pooled together and analyzed by analysis of variance (ANOVA) using OPSTAT programme. The comparison of treatment means was done by the least significant difference (LSD) at 5% probability ($P \leq 0.05$).

Results and Discussion

Grain Yield

Influence of different treatments of irrigation and establishment methods on wheat crop on grain yield is given on [Table-1]. The three years mean result revealed that wheat sown in conventional broadcasted field increased wheat grain yield which is closely followed by sown by happy seeder and zero tillage fields. However, the variation of conventional broadcast with respect to grain yield was non-significant as 1.31% and 0.21% as compared to zero tillage and happy seeder field, respectively. Similarly, different irrigation method had also not significantly influenced on grain yield of wheat in the study. The wheat raised with drip irrigation system gave the higher grain yield followed by flood irrigation method. The yield under sprinkler irrigation method recorded lower grain yield of wheat crop.

Table-1 *Wheat grain yield, physical water productivity (PWP) and economic water productivity (EWP) as influenced by irrigation and crop establishment methods in farmers field (Three years pooled from 218-19 to 2020-21)*

Treatments	Yield (kg ha^{-1})	PWP (kg m^{-3})		EWP (Rs. m^{-3})	
		IWU	TCWU	IWU	TCWU
Establishment methods					
Zero tillage	4795	5.69	3.17	109.05	60.61
Happy seeder	4848	6.16	3.34	117.85	63.94
Broadcasting	4858	6.83	3.44	130.85	65.86
SE(m)	58.56	0.06	0.04	1.26	0.54
LSD (P≤0.05)	NS	0.19	0.11	3.80	1.64
Irrigation system					
Flood irrigation	4820	2.36	1.83	45.19	35.04
Drip irrigation	4928	9.59	4.45	183.74	85.20
Sprinkler irrigation	4753	6.73	3.67	128.82	70.18
SE(m)	58.56	0.06	0.04	1.26	0.54
LSD (P≤0.05)	NS	0.19	0.11	3.80	1.64
Farmers' practice	4600	1.96	1.57	36.82	29.98
Interaction between E×I					
SE(m)	101.43	0.11	0.06	2.18	0.94
LSD (P≤0.05)	NS	0.33	0.19	6.58	2.84

Table-2 *Various water use studies as influenced by irrigation and crop establishment methods in farmers field (Three years pooled from 218-19 to 2020-21)*

Treatments	Total irrigation water used (m^3 ha^{-1})	Effective rainfall (m^3 ha^{-1})	Total water used (m^3 ha^{-1})	Water used to produced one kg grain yield (l kg^{-1})	WUE (kg/ha-mm)
Establishment methods					
Zero tillage	1139.1	589.3	1728.4	360.4	3.16
Happy seeder	1041.4	589.3	1630.8	336.9	3.34
Broadcasting	1099.0	589.3	1688.3	348.9	3.44
SE(m)	-	-	-	3.1	0.03
LSD (P≤0.05)	-	-	-	9.5	0.10
Irrigation system					
Flood irrigation	2050.0	589.3	2639.3	547.6	1.83
Drip irrigation	522.0	589.3	1111.3	225.7	4.45
Sprinkler irrigation	707.6	589.3	1296.9	272.9	3.67
SE(m)	-	-	-	3.1	0.03
LSD (P≤0.05)	-	-	-	9.5	0.10
Farmers' practice	2346.7	589.3	2936.0	638.3	1.57
Interaction between E×I					
SE(m)	-	-	-	5.4	0.06
LSD (P≤0.05)	-	-	-	16.4	0.17

The drip irrigation produced 3.68% and 2.24% higher grain yield over sprinkler and flood irrigation method, respectively. Effect establishment method did not influence significantly for wheat crops resulted in similar impact on grain yield of wheat. This may be due to effectiveness of drip irrigation system in conserving soil-moisture in the effective root zone which was continuously available throughout the growing period and result in less water stress in root zone of crop. Drip irrigation technology reduces the amount of irrigation and improves yield [12,13,14]. Tanmoy *et al*. [15] observed the yield variation in a study that grain yield of wheat crop in drip irrigation was increased by 29.8% than conventional farmer's practice. The finding of the present study confirms that wheat grown in drip irrigation with seed broadcast method had proven higher wheat grain yield [Fig-1]. However, this combined effect was statistically insignificant to all other methods. In this study noted that sprinkler irrigation recorded lower grain yield of wheat in all planting methods. the lower yield with sprinkler irrigation might be due to the impact of the sprinkler drops on the flower and the burning of the flowers and leaves by sunshine due to the lens effect resulted in low spikelets and eventually low yield. The same result is also corroborated with the finding of Kadiyala *et al*., [16].

Water Productivity

Physical Water Productivity (PWP)

Water productivity is calculated as the quantity of wheat grain yield harvested per unit of water used. PWP was taken into consideration for both irrigation water and total consumptive water uses.

[Table-1] shows that the PWP_{IWU} of conventional broadcasting method was significantly higher with 6.83 kg m^{-3}, followed by 6.16kg m^{-3}. Wheat raised by zero tillage had lesser PWP_{IWU} (5.69 kg m^{-3}). The higher yield and less water used in conventional broadcasting method resulted in higher PWP_{IWU}.

During the study period, drip irrigation method showed significantly higher PWP_{IWU} (9.59 kg m^{-3}) than in all other treatments followed by sprinkler irrigation method (6.73 kg m^{-3}). The PWP_{IWU} was found to be lowest with the flood irrigation method and farmers' practice since a large amount of water used to irrigate these plots. A study in rice experiment confirms that the average PWP_{TCWU} was reported to be 0.40 kg m^{-3} rice for Haryana state under farmer's conditions [11] and was 0.50 kg m^{-3} for Punjab. In addition to PWP_{IWU}, this study also evaluated the impact of planting and irrigation methods on PWP_{TCWU}. It is noted that the relationship between establishment and irrigation methods on PWP_{TCWU} follows the same general trend as PWP_{IWU}. The ranges noticed from 3.17 to 3.44 kg m^{-3} among the establishment methods. The result revealed that the PWP_{TCWU} of conventional broadcasting was higher followed by happy seeder. The zero-tillage recorded significantly lower PWP_{TCWU} during the entire study period. Among the irrigation methods, PWP_{TCWU} of drip irrigated was significantly higher (4.45 kg m^{-3}). The lower values (1.83 kg m^{-3}) of PWP_{TCWU} were recorded in the plots of flood treatment. From the analysis it can be tackled another fact about the good management of irrigation water leads in high water productivity and could be achieved by saving irrigation water under drip irrigation. Thus, drip irrigation could improve PWP of rice. The result was corroborated by Kato *et al*. [17] that water productivity of crops improved in drip irrigation. The higher water productivity in drip irrigation is the combined result of less consumption of water and comparatively higher grain yield. These results are in line with the results of Hanson & May [18] and Tripathi *et al*. [19].

Economic Water Productivity (EWP)

In this study, EWP also estimated to describe the principle of 'cost of water to society' by accounting the amount of irrigation water and the price of crop output in EWP computation.

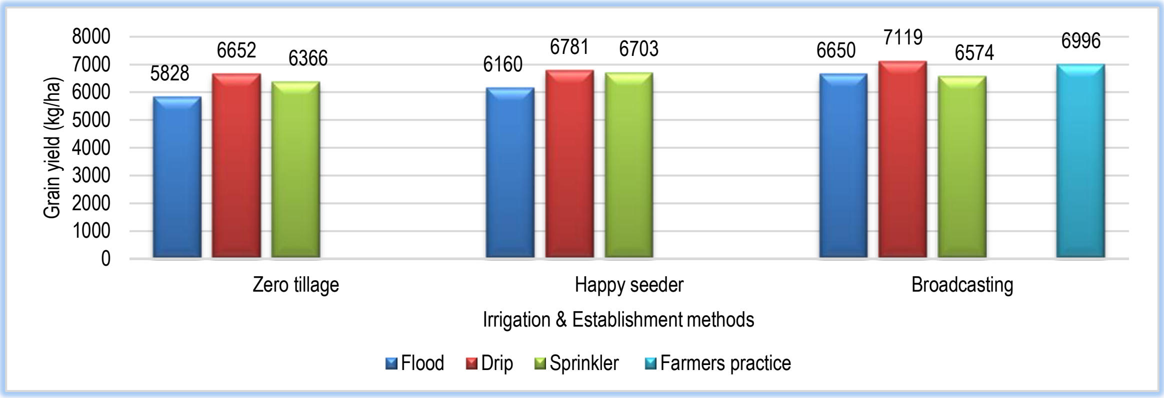

Fig-1 Interaction effect of irrigation and crop establishment methods on Grain yield of wheat (three years mean) in farmers' field

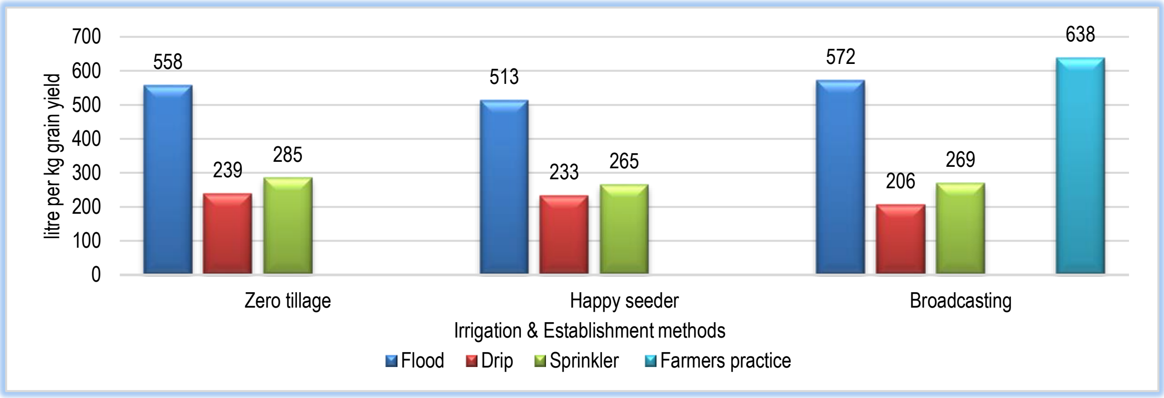

Fig-2 Interaction effect of irrigation and crop establishment methods on amount of water used to produce one kg grain yield of wheat (l kg^{-1}) in farmers' field

The EWP for IWS and TCWS was calculated and given in [Table-1]. The EWP_{IWS} under different planting methods ranges from Rs. 109.05 to 130.85 m^{-3} in the experiment. Conventional broadcasting method was significantly increased EWP_{IWS} in the study. It is a fact that there was lower EWP_{IWS} in all the plots of zero tillage planting methods. While irrigation methods, the ranges of EWP_{IWS} were Rs. 45.19 to 128.82 m^{-3}. The EWP_{IWS} of drip-irrigated rice was statistically comparable in all three years followed by sprinkler methods. The lower EWP_{IWS} was observed with flood irrigation methods. The farmers' practice had recorded lowest EWP_{IWS}.

In present investigation, EWP_{IWS} drip irrigation at conventional broadcasting performed superior to other treatments. Flood irrigation with zero tillage planted plots recorded comparably lower EWP_{IWS} in all three years. The consistent result was also seen for EWP_{TCWS} in all three years.

EWP_{IWS} was highest for drip irrigation indicating that the initial cost made in installing drip irrigation in a region is likely to generate large benefits. The mean EWP_{IWS} ¬of present investigation indicating that drip irrigation was increased by 4.99 and 4.07-fold than farmers practice and flood irrigation methods, respectively. The EWP_{TCWU} was also found to be highest in drip irrigation ((Rs. 85.20 m^{-3}) followed by sprinkler method (Rs. 70.18 m^{-3}) which showed about 2.84 & 2.43 fold higher than farmers practice and flood irrigation methods, respectively. This indicated that relating to the cost of irrigation water applied, general farmer's practices do not exhibit a sustainable EWP scenario. The non-judicious application of irrigation water in conventional irrigation method as commonly done by farmers for wheat crop is not sustainable. Sharma *et al.*,[11] have reported that in Haryana, the EWP of irrigated water for rice is Rs. 6.182 m^{-3}. Howell *et al.* [20] also suggested that excessive irrigation to produce maximum grain yield would not be the most efficient use of irrigation water.

Therefore, efforts must be taken to change the scenario from conventional wheat irrigation methods to micro-irrigation methods such as drip and sprinkler irrigation thus achieving more sustainability and food security for India. Further, farmers of Haryana are accessing virtually free electricity and canal water. Thus, there is a common propensity among the farmer's mind to excess irrigate the crop irrespective to actual crop water demand resulting in low values of EWP. Hence, this powerful nexus of water- energy resulting in inefficient use of both water and energy requirements must be addressed on priority. Therefore, drip and sprinkler methods have a big opportunity to improve wheat productivity with low water use on a sustainable basis. There is a need to accomplish a comprehensive evaluation of EWP on the impact of micro-irrigation. These results can be used in persuading farmers to adopt micro irrigation.

Water use studies

The total water used, water used to produce one kg wheat grain yield and water use efficiencies are given in [Table-2]. The total water use inclusive of effective rainfall in flood irrigation of farmers practice was 2936 m^3. Among the establishment methods, the least amount of water used in happy seeder. While, drip irrigation method used lower water quantity with 1111.3 m^3 followed by sprinkler method. The flood irrigation method used huge amount of water in the study with 2639.3 m^3.

The result revealed the irrigation methods, drip irrigation had recorded less amount of water to produce one kg grain yield (225.7 l kg-1) followed by sprinkler irrigation (272.9 l kg-1). It showed that drip and sprinkler irrigation used 2.43 and 2.01 times lower water than flood irrigation method, respectively. Further [Fig-2] showed drip irrigation in all the planting methods showed significantly lowest water used to produce one kg grain yield. Particularly, it was spectacular performance noticed in conventional broadcasting method.

The irrigation methods, the higher WUE was observed under drip (4.45 kg/ha-mm) followed by sprinkler (3.67 kg/ha-mm) methods. The flood irrigation method had lower WUE in the study. The drip irrigation methods used less water due to restriction of water loss through evaporation from large amount of ground, conveyance losses resulted in maximum water use by crops. The same result was also corroborated by Tanmoy *et al.*, [15]. Similar result of water saving under drip irrigation was pointed out by Veeraputhiran [21] and Chouhan *et al.*, [22].

Conclusion

The present study found consistent evidence that the adaptation of drip irrigation combined with wheat in manual planting method offered substantial agronomic and economic advantages.

Wheat yield were found to be significantly higher in drip irrigated treatments. The evidence assembled and analyzed here suggested that wheat under drip irrigation was a promising adaptation for higher water productivity in terms of physical and economical point of view. It also reduces the wheat crop's demand for water and energy, which are increasingly demanded and costly, while the same time it raised grain yield. However, long term multi-location trials will be needed to explore in-depth study on different water productivity that are achievable under varied and specific conditions.

Application of research: Water conserving crop production technology for wheat is very pertinent and will be of use to the farmers.

Research Category: Agronomy on farm.

Abbreviations:
WUE- Water Use Efficiency; MI- Micro Irrigation; PWP- Physical water productivity; EWP - Economic Water Productivity; IWU - Irrigation Water Use; TCWU - total cumulative water use (irrigation +rainfall).

Acknowledgement / Funding: Authors are thankful to Jain Irrigation System Ltd. Jalgaon, 425001, Maharashtra, India and Department of CADA, Government of Haryana.

****Principal Investigator or Chairperson of research: Dr P. Soman**
Institute: Chief agronomist Global, Jain Irrigation systems Ltd.
Research project name or number: Part of research project -Adoption of micro irrigation for cereals- Wheat and Rice

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Farmers field in Haryana

Cultivar / Variety / Breed name: Wheat (*Triticum aestivum* L.)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

References

[1] Alexandratos N. and Bruinsma J. (2012) World Agriculture towards 2030/2050: the Revision ESA Working Paper No. 12-03; Agricultural Development Economics Division; Food and Agriculture Organization of the United Nations (FAO): Rome, Italy, 2012.
[2] Ayars J.E., Fulton A. and Taylor B. (2015) *Agric. Water Manag*., 157, 39-47.
[3] Al-Ghobari H.M. and Dewidar A.Z. (2018) *Agric. Water Manag*., 209, 55-61.
[4] Siebert S., Burke J., Faures J.M., Frenken K., Hoogeveen J., Döll P. and Portmann F.T. (2010) *Hydrol. Earth Syst. Sci*., 14, 1863-1880.
[5] Wada Y., Beek L.P.H. and Bierkens M.F.P. (2012) *Water Resour. Res*., 48.
[6] Lu C. and Fan L. (2013) *Field Crops Res*., 143, 98-105.
[7] Sun H., Shen Y., Yu Q., Flerchinger G.N., Zhang Y., Liu C. and Zhang X. (2010) *Agric. Water Manag*., 97, 1139-1145.
[8] Shen Y., Zhang Y., Scanlon R.B., Lei H., Yang D. and Yang F. (2013) *Agric. For. Meteorol*., 181, 133-142.
[9] Leghari S.J., Soomro A.A., Laghari M.G., Talpur H.K., Soomro A.F., Mangi H.M., *et al*. (2018) *AIMS Agric. Food*., 3, 397-405.
[10] Scott R.L. (2010) *Agric. For. Meteorol*., 150, 219-225.
[11] Sharma B.R., Gulati A., Mohan G., Chanda S., Ray I. and Singhe U. (2018) *Water productivity mapping of major Indian crops. NABARD and ICRIER Report*.
[12] Liao L., Zhang L. and Bengtsson L. (2008) *Irrig. Drain. Syst*., 22, 253-70.
[13] Wang R., Wang X., Fu L., Zhao B. and Zhang W. (2010) Xinjiang Agric. Sci., 47, 1412-15.
[14] Wang J., Xv Y., Gao S., Han X. and Xv C. (2011) *Agric. Res. Arid Areas,* 29, 21-26.
[15] Tanmoy Bhowmik, Bhardwaj A.K., Pandiaraj T. and Roy A. (2018) *Int. J. Curr. Microbiol. App. Sci*., 7(02), 3185-3191.
[16] Kadiyala M.D.M., Mylavarapu R.S., Li Y.C., Reddy G.B. and Reddy M.D. (2012) *Agron. J*., 104, 1757-1765.
[17] Kato Y., Okami M., and Katsura K. (2009) *Field Crops Res*., 113, 32 8-334.
[18] Hanson B.R. and May D.M. (2005) *Agr. Water Mgt*., 81, 381-399.
[19] Tripathi P.C., Sankar V. and Lawande K. E. (2010) *Indian J. Horti*., 67(1), 61-65.
[20] Howell T.A., Cuenca R.H. and Solomon K.H. (1990) *Crop yield response. In: Hoffman G.J., et al (eds.), Management of Farm Irrigation Systems. Am. Soc.Agric. Eng (ASAE) St. Joseph, MI*, pp 93-122
[21] Veeraputhiran R. (2000) *Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore*
[22] Chouhan S., Manoj Kumar, Awasthi M.K. and Nema R.K. (2015) *Indian J. Sci. Tech*., 8, 650-654.