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EVALUATION OF IRRIGATION SCHEDULING TECHNIQUES: A CASE STUDY OF WHEAT CROP SOWN OVER PERMANENT BEDS UNDER SEMI-ARID CONDITIONS

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Abstract

The present study was carried out at Water Management Research Centre (WMRC), University of Agriculture Faisalabad, Pakistan to optimize the water usage for wheat crop in water scare regions of the country. Two main irrigation scheduling approaches i.e soil-moisture-based and climatic based were adopted and compared. There were overall six treatments; three treatments were for testing of climatic approach of irrigation scheduling i.e. application of irrigations at 20 mm (TC1), 30 mm (TC2) and 40 mm (TC3) Cumulative Pan Evaporations (CPE), and three treatments were for soil-moisture-based approach of irrigation scheduling i.e. 30% (TS1), 45% (TS2) and 60% (TS3) of Management Allowable Depletion (MAD) levels, and one farmer's practice (Fp). Another aspect of the study was to check the ability of an in-season Normalized Difference Vegetation Index (NDVI) measurements to predict wheat yield potential. Results showed that the soil-moisture-based treatments significantly increased wheat grain yields over climate-based treatments (TC2 and TC3) and non-significantly over TC1. Results of NDVI measurements showed that it can be used for accurate in-season wheat grain yield estimation with R2, RMSE, Cv, ME, RE, Bias and NSE estimated 0.768, 17, 4.4, 0.07, 0.019, 0.073 and 0.84 respectively and can be used as a valuable crop management tool.

Key words: *soil moisture, cumulative pan evaporation, management allowable depletion, normalized difference vegetation index, grain yield*

INTRODUCTION

In Pakistan, wheat (Triticum aestivum L.) is one of the major crops and it is grown on a large area. It contributes 9.1% of the total value added of the agricultural sector and 1.7% of the gross domestic product of Pakistan (GoP, 2018). It has a dominant status in the formulation of agriculture sector policies in the country (Mangrio et al., 2016). Wheat production in the country for the economic year 2017-18 was 25.492 million tons from an area of 8734 thousands hectares (GoP, 2018). Punjab is the largest wheat producing province of Pakistan with a contribution of around 76% of the wheat production from 75% wheat area of the country (GoP, 2015). Irrigation water is one of the important inputs controlling the productivity of wheat crop.

The water availability in Pakistan has approached about 1000 m3/capita, categorizing the country as a water deficit country (Bakhsh et al., 2015 and Ansari et al., 2017). Moreover, projections show that the current pace of increasing population may lower water availability to 915 m3/capita in 2020 (GoP, 2014). Under these circumstances, there is a need to apply irrigation water efficiently to increase water productivity, which has been reported to be as low as 0.2 kg/m3 of water (Ceema et al., 2016). The traditional practice used for increasing productivity is extensive utilization of resources like fertilizer and water. Eventually, it increases the production cost and overuse of the inputs which in turn not only suppress overall yield but cause problems like weed growth, plant diseases, soil degradation, and ineffectiveness of pesticide. Hence, an appropriate management of irrigation water is considered necessary for sustainable production and high-water use efficiency.

Crop water requirement varies from crop to crop and it fluctuates daily with the climate conditions. Pan evaporation (PE) integrates all the climatic parameters (Solar radiation, temperature, wind speed, relative humidity etc.) for determining crop water demand (Joshi et al., 2017). In this study the crop water requirement was assessed from pan evaporation method. However, PE does not be similar to the actual use of water by crops but it is driven by similar atmospheric variables and correlates relatively well with crop water use or potential ET (Penman, 1948). The crop evapotranspiration models and equations, for example Penman or the later Penman-Monteith equation requires a large number of climatological datasets (Solar radiation, maximum and minimum temperature, wind speed, relative humidity, etc) and it is also a complex method. Allen et al., (1998) found that the PE method provide a good estimate of reference evapotranspiration (ETo) when suitable pan coefficients of that area are applied. Lee et al., (2004) compared eight methods of estimation of evapotranspiration with daily data of 30 years and found no significant difference among PE method, Penman-Monteith method and Blaney-Criddle method at 0.05 probability.

Management Allowable Depletion (MAD) in soil moisture was used to schedule irrigation for wheat crop. MAD is the level of moisture depletion in available soil moisture to which a crop withstands without any adverse effect on it (Markewitz et al., 2010). Panda et al., (2003) observed maximum field water use efficiency at 45 % MAD even for the non-critical growth stages of wheat crop. Laghari (2009) found that maximum yield and crop water use efficiency was obtained when irrigation was scheduled at 55% MAD of Available Soil Moisture (ASM) for wheat crop and at 65% MAD of ASM for cotton crop.

Crop yield predictions play supporting role in decision-making and policy formulations on both regional and global scale. At the field level, the crop yield prediction information, particularly related to crop management decisions as crop performance, growth, and development are the desegregating factors that evaluate the efficiency of the adopted agricultural management practices within the boundaries of the agro-ecological environment (Choudhary et al., 2012). Particularly, much of the grain yield production capacity of wheat crop is related to growth during a few weeks before anthesis (Marti et al., 2007). Thus, the in-season yield prediction is used as a tool for deciding on management options for the rest of the crop stages. The use of spectral reflectance indices, such as the NDVI, has been proposed as a fast, nondestructive way to monitor crop condition and estimate crop growth capacity (Mutiibwa and Irmak 2013; Waqas et al. 2019). NDVI is an index which is a measure of vegetation density and condition. The NDVI can be calculated from reflectance measurements in the red and near infrared (NIR) portion of the spectrum. Its values range from −1 (usually water deficit) to +1 (strongest vegetative growth). The optical properties of the leaf tissues, their cellular structure and the air-cell wall protoplasm-chloroplast interfaces determined the reflectance in the NIR range (λ = 700–1300 nm) and in the Red range (λ = 550–700 nm) (Kumar and Silva, 1973).

The present study was an attempt to assess the effect of different irrigation schedules on the crop yield parameters. The whole study was carried out with the two main objectives; i) To study the effects of climate based and soil-moisture-based irrigation schedules on wheat yield parameters and ii) To determine the ability of NDVI to predict an in-season estimation of wheat yield potential.

MATERIAL AND METHODS

Experimental Site

The study was carried out at the experimental plots of WMRC, Faisalabad, Pakistan, on wheat crop for Rabi 2014-15. The local climate of the area is semi-arid with an average annual rainfall of 350mm, concentrated mostly over the months of June to August. A total of 133 mm rainfall was received in the whole growing season (from November to April), especially during March to April. Monthly means that maximum temperature observed was 33.2 °C in the month of April and monthly mean minimum temperature observed was 5.9 °C in the month of December. The weather data of the experimental site for the whole growing season are given in Table 1. Three bulk soil samples were made from nine sub samples taken from three depths (0-15 cm, 16-30 cm, and 31-45 cm) at three different locations within the field. The soil texture in the study area was tested and found as sandy loam. All physical and chemical properties show a little variation throughout the study area and at different depths. The soi'sl physical and chemical properties at the experimental crop field are given in Table 2.

Table 1. Weather data of the experimental site throughout the growing season.

Month	Monthly Mean Max. Temperature (°C)	Monthly Mean Min. Temperature (°C)	Monthly Mean Relative Humidity (%)	Rainfall (mm)	Monthly Mean Sunshine Hours (Hrs)	Monthly Avg. Wind Speed (Km/hr)
November	26.3	11.5	61.7	0	7.6	3.1
December	18.5	05.9	75.0	0	4.7	2.0
January	16.6	06.9	75.3	11.12	5.0	3.6
February	22.0	11.1	66.0	20.5	5.6	5.3
March	24.5	13.6	64.0	67.9	4.9	5.6
April	33.2	20.7	43.9	32.8	9.1	6.2

Table 2. Soil physical and chemical properties of the experimental site.

Soil Depth Layers (cm)	Physical characteristics							Chemical characteristics				
	Sand (%)	Silt (%)	Clay (%)	Soil Type	Bulk Density (g/cc)	Field Capacity (%)	Wilting Point (%)	pH	EC (dS/m)	OM (%)	P (ppm)	K (ppm)
0-15	63	23	14	Sandy loam	1.54	21.7	8.42	8.40	1.32	0.45	1.8	100
16-30	67	19	14	Sandy loam	1.56	21.3	8.00	8.27	1.30	0.43	1.7	87
31-45	66	18	16	Sandy loam	1.55	21.8	8.45	8.25	1.33	0.46	1.5	73

P: Phosphorus, K: Potassium, OM: Organic Matter

Field Layout and Experimental Details

The experiment was comprised of three main plots; two plots for testing irrigation scheduling techniques (Climate based and soil moisture based) with three levels on each plot and replicated three times arranged in Complete Randomized Design (CRD), one plot for farmer practice treatment (Fp). Climate-based irrigation scheduling was accomplished using predefined cumulative pan evaporation (CPE) and Soil-moisture-based irrigation scheduling was done using the temporal soil moisture measurements. The three levels of each irrigation scheduling technique is given below:

1) Climate based
   TC_1= 20 mm CPE
   TC_2= 30 mm CPE
   TC_3= 40 mm CPE

2) Soil-moisture-based
   TS_1= 30% MAD of ASM
   TS_2= 45% MAD of ASM
   TS_3= 60% MAD of ASM

Sowing

The wheat crop was sown at mid-November using bed-furrow wheat planter. The seeding was done at the rate 125 kg/hectare at 0.0254 meter depth. The selected plot contained permanently raised beds. The beds were made two years earlier. Before sowing of wheat crop, cotton was sown over the same beds. Traditional soaking irrigation (Rouni irrigation) was not applied as enough moisture was present in soil. The total area was 1170 square meters. There were total 18 beds. Each bed was 67 meters long and 0.61 meters in width with 0.3048-meter space for furrow. Nine beds were reserved for trials for irrigation schedules based on climatic indicator (i.e. CPE) and remaining nine beds were reserved for the trials of irrigation schedules based on soil moisture depletions. Farmer practice was conducted on the adjacent field. The sowing method, plant protection and fertilizer application were same as other treatments.

Plant protection and fertilizer application

Three types of fertilizers were applied; i) Urea as a source of nitrogen at the rate of 48 Kg-N/ha, ii) Di-Ammonium Phosphate (DAP) as a source of phosphorus at the rate of 52 Kg-P/ha and iii) Muriate of Potash (MOP) as a source of potassium at the rate of 64 Kg-K/ha. Plant protection measures including herbicides and all other cultural practices were also carried out during its growth period whenever required for all the treatments. Buctril Super (Bromoxynil) and Topik (clodinafop-propargyl) were used for broadleaf and grass weeds at the rate of 740 mL/ha and 296 g/ha, respectively.

Irrigation Scheduling

Climate-based irrigation scheduling was accomplished using predefined CPE. Class A type evaporation pan was used for the estimation of pan evaporations. The average value of pan coefficient (K_p) was considered as 0.7 (Ken University lectures: Accessed online) and the crop coefficient (K_c) values for different growth stages were taken from the working paper 24 of International Water Management Institute (IWMI) (Ullah et al., 2001). Amount of water applied was calculated by using following formula:

$$I = E_{pan} \times K_{pan} \times K_c \qquad (2)$$

Where, I is irrigation water depth (in mm), E_{pan} is pan evaporation (in mm), K_{pan} is pan coefficient (0.7), K_c is the crop coefficient

Soil-moisture-based irrigation scheduling was done by using the temporal soil moisture measurements using Time Domain Reflectometer (TDR). Similarly, irrigation was applied at 18%, 16% and 14% soil moisture content for 30% MAD, 45% MAD and 60% MAD respectively to fill up the root zone up to field capacity.

The percent depletion of ASM in the effective root zone was estimated using following Eq. 3 (Martin et al., 1990),

$$MAD(\%) = 100 \times \frac{1}{n} \sum_{1}^{n} \frac{FC_i - \theta_i}{FC_i - WP} \qquad (3)$$

Where, n is the number of sub-divisions of the effective rooting depth, θ_i is the soil moisture in i^{th} layer (in %), FC_i is the soil moisture at field capacity for i^{th} layer (in %), WP is the soil moisture at permanent wilting point (in %)

The volume of irrigation was calculated by the Eq. 4.

$$V_d = \frac{MAD(\%) \times (FC - WP) \times R_z \times A}{100} \qquad (4)$$

Where, V_d is the volume of irrigation water (in m^3), R_z is the effective rooting depth (in m), A is the surface area of plot (in m^2)

In Fp treatment, water was applied according to farmer's practice (irrigation water was applied at different growth stages without considering the soil moisture, evapotranspiration or crop stress) and implemented in adjacent field of the research area.

Crop Yield Prediction

Active remote sensing based NDVI measurements were taken using a spectro-radiometer (handheld Greenseeker optical sensor) above the canopy at 50 cm height at different growth stages during the season. The linear relationship between NDVI and grain yield was determined using correlation coefficient (r) for measuring the strength of association between NDVI and grain yield at all growth stages. A simple linear regression model was developed between NDVI and actual grain yield at maximum correlated stage. Twelve plots (67% of the total plots) were randomly selected for this purpose. The remaining 33% (6 plots) were used for validation purpose. The mean error (ME), the relative error (RE), the root mean square error (RMSE), coefficient of variation (Cv), R^2 and Nash-Sutcliffe model efficiency (NSE) were used for model evaluation (Saeed et al. 2017).

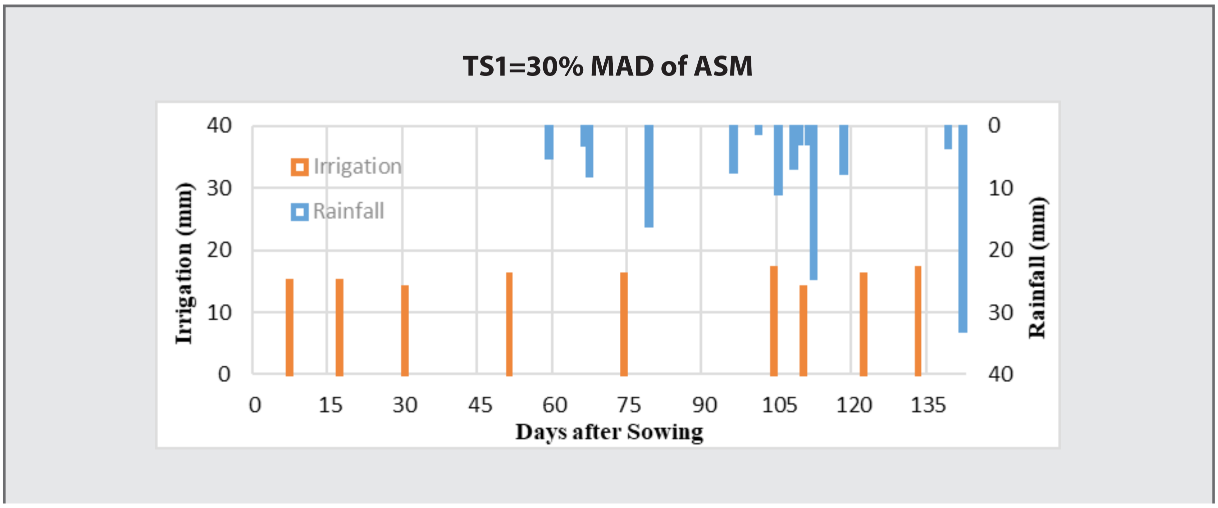
Harvesting

Crop was harvested in the last week of April. An area (0.6 m^2) at head, mid and tail section from each plot was harvested and sub samples of 10 plants were selected randomly for the determination of different yield components. All samples were threshed manually for the estimation of grain yield and biological yield. The grain yield data and other crop parameters (spike length, no. of grains per spike, plant height, and biological yield) were statistically analyzed using analysis of variance (ANOVA) with comparison of means using Least Square Difference (LSD) test at $P \leq 0.05$.

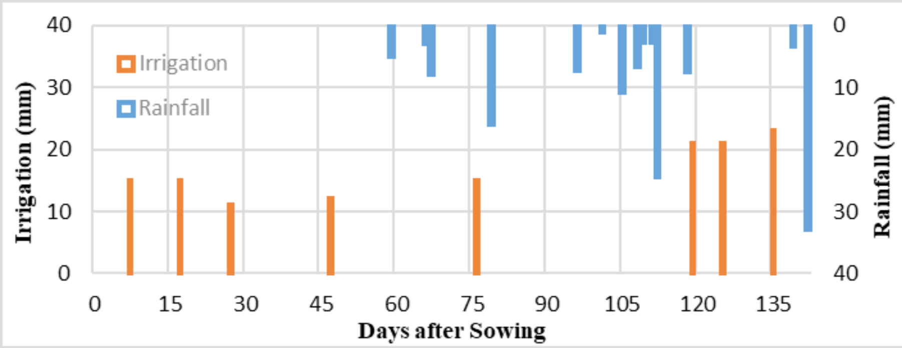
RESULTS AND DISCUSSION

Irrigation Scheduling

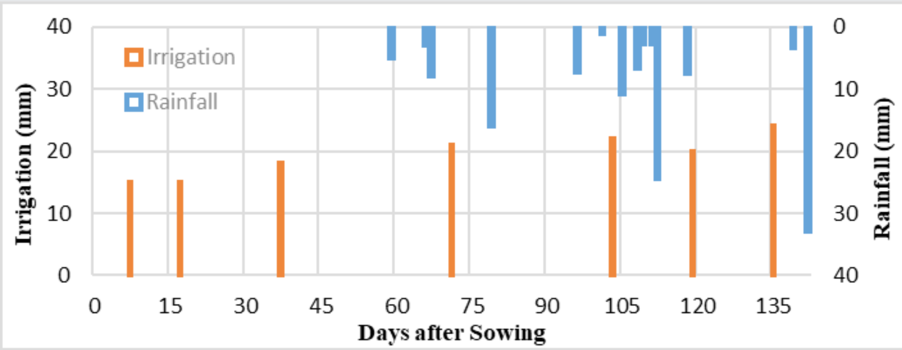
The frequency and quantity of irrigation water are critical in wheat crop production. The water stress timing can cause significant variation in grain yield (Akram, 2011; Mirbahar et al., 2009; Patel et al., 2008; Behra and Panda, 2009). The crop water needs were fulfilled by rainfall and irrigation water. The irrigations were applied through drip irrigation system except first watering (seven days after sowing) which applied through flooding method as proportionate amount of irrigation water was applied (30 mm total) for uniform germination of wheat. The rainfall used by plants was taken 70 percent of total rainfall and termed as effective rainfall. The whole growing season (from November 15 to April 21) received 92 mm effective rainfall. In first half of the growing season as no rainfall event occurred, and the crop water requirements were fulfilled by irrigation water only. In the later part of the growing season, temperature conditions turned into warmer, and total fourteen rainfall events were recorded which partially fulfilled the crop water requirements. The last rainfall of the crop season was lesser utilized by the crop due to maturity stage of the crop. In soil-moisture-based schedules, soil water depletion rates were used to determine the time of irrigation. In case of 30% MAD, Irrigation water was applied when soil moisture contents reached at 18% to fill up the root zone up to field capacity. Similarly, irrigation was applied at 16% and 14% soil moisture content for 45% MAD and 60% MAD respectively. The number of irrigations for TS1was greater than TS2 and TS3, as TS1 was low volume and high frequency treatment (least stressed) whereas TS3 was high volume and low frequency treatment (most stressed).



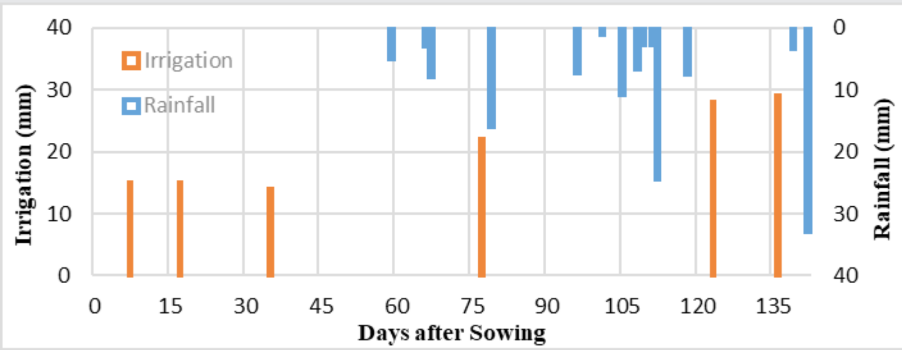
TC1=20 mm CPE



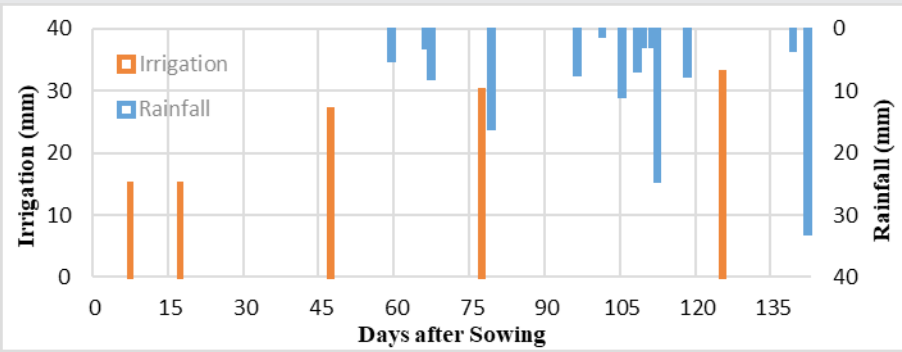
2=45% MAD of ASM



TC2=30 mm CPE



TS3=60% MAD of ASM



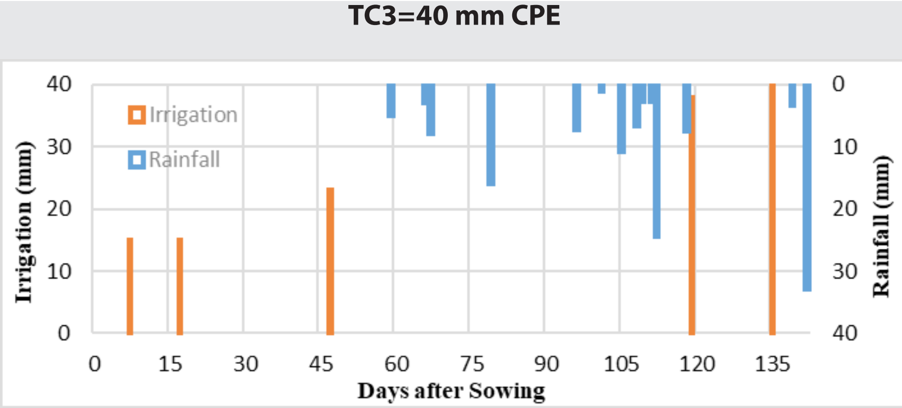


Figure 1. Irrigations scheduled and rainfall events recorded for all treatments.

The predefined levels of MAD were achieved throughout the growing season by applying total nine, seven and five irrigations in TS1, TS2 and TS3 treatments, respectively. In climate-based schedules, evaporation rates were used to determine the time of irrigation. For TC1 treatment, irrigation was applied, when cumulative pan evaporation reached at 20 mm. In the same way, water applied at 30 mm and 40 mm CPE for TC2 and TC3 treatments. The TC1 is the low volume high frequency treatment (least stressed) while TC3 is the high volume and low frequency treatment (most stressed). In the whole growing season, total eight, six and five irrigations were applied in TC1, TC2 and TC3 treatments, respectively. The water application in terms of rainfall and irrigation for all treatments are shown in Figure 1. The total water application from both sources irrigation and rainfall varied from 212 mm to 232 mm for all treatments except farmer practice, in which water was applied at a rate of 350 mm per season. Overall, the quantity of water applied based on soil moisture approach were greater than that of applied based on climatic approach.

Effect of water stress timing on grain yield

The effects of different irrigation schedules, based on climate and soil moisture data, on the development of grain yield of wheat crop was investigated during the study. The growth parameters considered in the current study were plant height at harvest, spike length at harvest, average number of grains per spike, biological yield, grain yield are shown in Table 3 with statistical analysis. Grain Yield, biological yield, and irrigation water productivity followed the same trend (i.e. TC1>TC2>TC3 and TS1>TS2>TS3) within each set of treatments of climate and soil-moisture-based approach. However, average plant height, average spike length and average number of grains per spike showed irregular trends. Regarding about grain yield, TS1 gave maximum yield (4.35 t/ha) while minimum yield was obtained with TC3 treatment (3.32t/ha). In case of biological yield, maximum (12.50 t/ha) and minimum (11.55 t/ha) yield were recorded with TS1 and TC3 treatments respectively. The significant difference was observed for all parameters except crop water use, plant height and spike length at harvest. Results of LSD pair-wise comparison test for three climate-based treatments showed that the irrigation schedule at 20 mm CPE resulted in significantly higher grain yield over 40 mm CPE and non-significantly over 30 mm CPE. Irrigation schedule at 30 mm and 40 mm CPE generated non-significant results. The results of three soil based treatments showed non-significant difference for grain yield. Overall, soil moisture-based treatments (30%, 45% and 60% MAD) significantly increased wheat grain yields over climate-based treatments (30 mm and 40 mm CPE) and non-significantly with 20 mm CPE climatic treatment.

Table 3. Effect of different irrigation schedules on wheat yield and its component.

Treatments	Crop water use (mm)	Plant height at harvest (cm)	spike length at harvest (cm)	No. of grains per spike	Biological yield (t/ha)	Grain Yield (t/ha)
TC1	225	99	12.67	65a	12.12cd	4.03bc
TC2	215	98	12.00	57b	11.81e	3.67d
TC3	225	97	12.00	55b	11.55f	3.32e
TS1	232	95	12.00	61ab	12.50a	4.35a
TS2	227	98	12.33	60b	12.28b	4.24ab
TS3	212	99	11.67	57b	12.05d	3.94c
LSD 5%				5.42	0.15	0.27
Significance	ns	ns	ns	*	*	*

*=Significant ns =non-significant

The maximum yield obtained among soil-moisture-based treatments (i.e. in TS1) was 7.94% higher than that of obtained among climate-based treatments (i.e. TC1), and gave 31% and 28 % more grin yield than TC3 and Fp treatment. The yield difference among all treatments were attributed to the first half of the season. The yield reduced for high volume and low frequency treatments as crop is its initial stage and it's become difficult for root system to extract sufficient soil water from a greater depth, thus limiting its water uptake (Ahmed et al., 2012), which consequently effect the plant growth and yield. Shiva et al., (2017) reported higher root water uptake for least stressed schedule (70% of FC) and decreased with less frequent amounts of irrigation (50% and 60% of FC). These results are in concord with the findings of Blonquist Jr et al., (2006) and Khalilian et al., (2007) while opposite results were found in Taber (2007) study. The irrigation water productivity was used to check the efficient utilization of water and presented in Figure 2. It is the ratio of grain yield produced per volume of water applied. Regarding the irrigation water productivity, its indicates the how efficiently water applied and used. The highest value was obtained for TS1 treatment (1.875 kg/m^3) and lowest for farmer practice (0.971 kg/m^3). Although lowest grain yield was recorded for TC3 treatment but it's still better schedule than farmer practice, as irrigation water productivity was higher for TC3 (1.475 kg/m^3) than Fp treatment (0.971 kg/m^3). Comparable results were reported by Shiva et al., (2017) who found the highest water productivity(2.08 kg/m^3) in drip irrigation method scheduled at 60% of field capacity and was the lowest in surface flooding method scheduled at 70% of field capacity (1.86 kg/m^3).

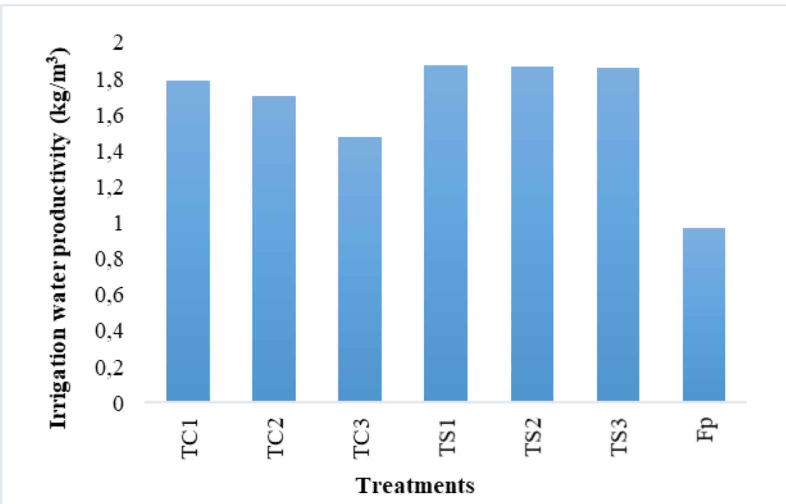


Figure 2. Graphical representation of grain yield and crop water use.

NDVI and yield prediction

NDVI based crop growth dynamics curves were developed for the same experimental data and shown in Figure 3. As expected, the NDVI values were low in early season and gradually increased with crop growth and reached a plateau in mid-season at the time when the ground surface was completely covered by the crop canopy. The plateau in NDVI curves seems to correspond to the saturation of the sensor and eventually loss of its sensitivity to measure changes in vegetation when leaf area index (LAI) is higher than 3 (Aparicio et al., 2000; Carlson and Ripley, 1997; Duchemin et al., 2006; Naser, 2012). The decrease in NDVI values at the end of the season is due to the physiological crop maturity, change in crop color and senescence leaf, which increases red band reflectance and decreases NIR band reflectance.

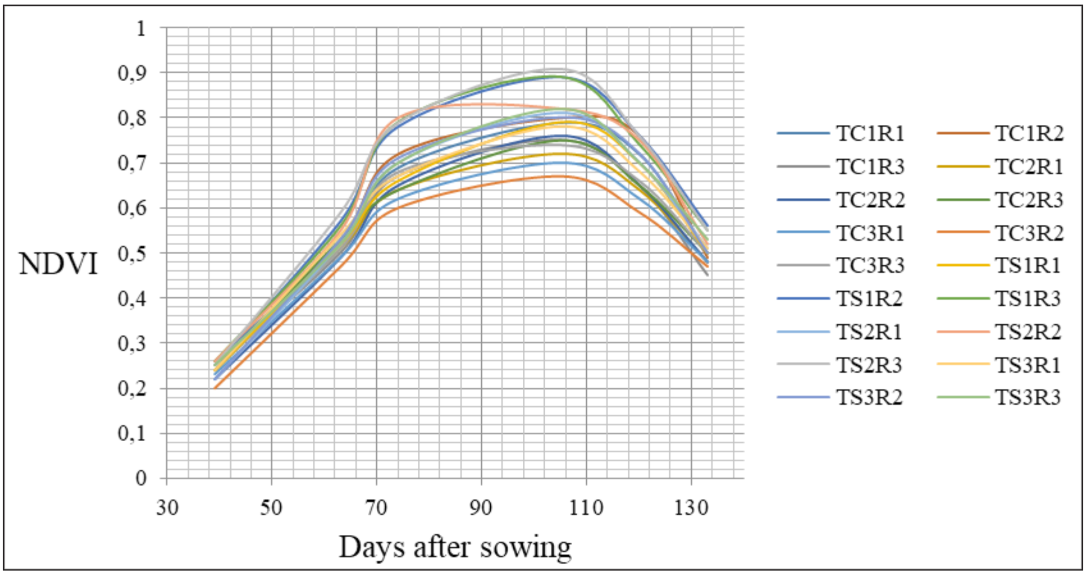


Figure 3. NDVI based crop growth dynamics curves.

Time of measurement is an important factor in determining the feasibility of integrating predicted yield under different water management practices. The correlation coefficient (R^2) between grain yield and NDVI was determined for all treatments at all growth stages. At the time of tillering, shooting, booting, anthesis, and milk maturity NDVI values were highly positively correlated with grain yield. Results of correlation coefficient suggested that NDVI measurements taken at heading stage could assist with more accuracy in predicting grain yield as compared to other developmental crop growth stages. Teal et al., (2006) studied that the NDVI readings after heading stage were unable to discriminate variations, whereas at early growth stages yield potential had not yet completely developed. A simple linear regression model was developed between actual grain yield and NDVI at heading stage for randomly selected 12 plots (67% of the total), shown in Figure 4. It showed a good agreement (R^2=0.873). According to Walsh et al., (2013) there is a good relationship between NDVI and actual wheat grain yield. at the Feekes 5 growth stage (end of tillering stage) and explained 82%, 69% and 88 % of variation in grain yield at Lahoma in 2008, at Perkins in 2008 and at Lahoma in 2009, respectively. The regression model developed between NDVI and grain yield by Naser (2012) showed a strong relationship at mid-grain filling stage with coefficient of variation 0.83. Identical results were found in the studies of Sultana et al., (2014) which were performed in similar environmental conditions. At country level, Ren et al., (2008) found good agreement between NDVI and grain yield with R^2=0.8, whereas Liaqat et al., (2017) reported this relationship with R^2=0.50.

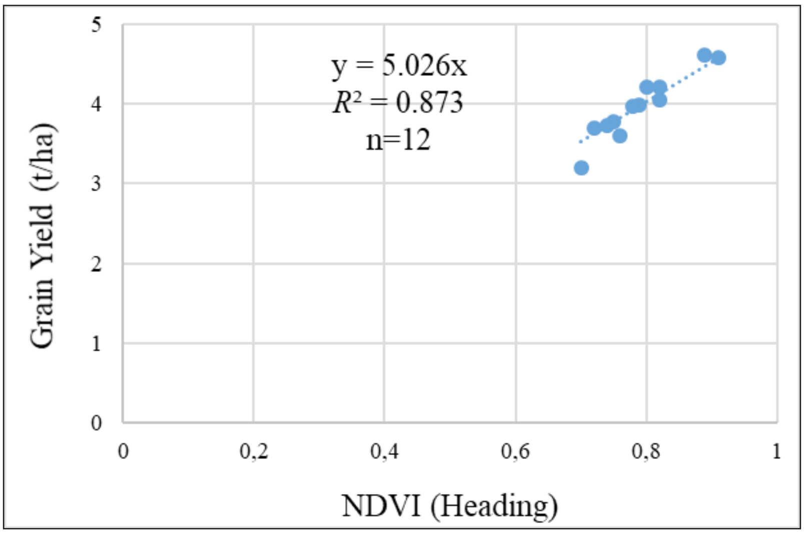


Figure 4. Relationship between Actual grain yield and NDVI at heading stage.

In validation process, a cross check analysis was performed. The accuracy of the developed regression model was evaluated. Validation analysis was done on the remaining 33% of the total plots (six plots). The comparison between actual and estimated values of grain yield were made as a percentage deviation and presented in Table 4. The validation showed that there exists a good agreement between predicted and actual wheat grain yield. Different evaluation parameters for the developed regression model are also given in Table 4. Ren et al., (2008) found similar results in Shandong, China with relative error varied from 4.62% to 5.40% and that regression coefficient (R^2) reached to 0.87.

Table 4. Measured vs. simulated results and statistical assessment.

Actual Yield (t/ha)	Estimated yield (t/ha)	
4.1	3.97	
3.8	3.77	
3.05	3.37	
4.44	4.47	
4.05	4.07	
3.79	4.02	
Evaluation Parameters		
R2		0.768
RMSE (%)		17
CV (%)		4.4
Bias		0.073
ME		0.07
RE		0.019
NSE		0.84

CONCLUDING REMARKS

In conclusion, the soil moisture information is more reliable for irrigation scheduling than climatological information (cumulative pan evaporation). The soil-moisture-based treatment TS1 (30% of MAD), yielded 7.94% more crop yield than irrigation scheduling at even lower level such as TC1 (20 mm CPE) of climate-based treatments for wheat crop grown in sandy loam soil.

Results of NDVI measurements showed that NDVI can be used for accurate (R^2=0.768) in-season wheat grain yield estimation at heading stage (105 days after sowing), compared with other development stages and can be used for crop management. Additional plant spectral indices, less prone to saturation at high biomass situations, may be used to help prediction of crop yield in higher crop growth stages.

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ЕВАЛУАЦИЈА НА ТЕХНИКИТЕ НА РАСПОРЕДУВАЊЕ НА НАВОДНУВАЊЕТО: СТУДИЈА НА СЛУЧАЈ НА ПЧЕНИЦА ЗАСЕАНА ВО ПОСТОЈАНИ ЛЕИ ВО ПОЛУСУШНИ УСЛОВИ

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Резиме

Оваа студија беше спроведена во Истражувачкиот центар за управување со вода (WMRC) на Универзитетот за земјоделство Фаислабад, Пакистан, за да се оптимизира потрошувачката на вода за културата пченица во региони на земјата сиромашни со вода. Беа усвоени и споредени два главни пристапи за планирање на наводнување, т.е. базирано на почвена влага и на климатски фактори. Имаше вкупно шест третмани: три третмани беа за тестирање на климатскиот пристап за планирање на наводнувањето т.е. примена на наводнување на 20 mm (TC1), 30 mm (TC2) и 40 mm (TC3) кумулативно испарување мерено во сад за испарување (CPE), и три третмани се однесуваа на пристап базиран на почвена влага за планирање на наводнување т.е. 30% (TS1), (MAD) 45% (TS2) и 60% (TS3) од нивоата на максималната количина на вода достапна за растенијата (MAD) и една практика на фармерите (Fp). Друг аспект на истражувањето беше да се провери способноста на сезонско мерење на сушата (NDVI) за да се предвиди потенцијалниот принос на пченица. Резултатите покажаа дека третманите базирани на почвена влага значително го зголемиле приносот на пченица во зрно во однос на третманите базирани на клима (TC2 и TC3) и незначително во однос TC1. Резултатите од NDVI мерења покажаа дека тоа може да се користи за точна проценка на сезонскиот принос на зрно пченица со R2, RMSE, C_v, ME, RE, Bias и NSE проценка 0,768; 17; 4,4; 0,07; 0,019; 0,073 и 0,84, соодветно, и може да да се користи како важна алатка за управување со култури.

Клучни зборови: *почвена влажност, кумулативно испарување мерено во сад за испарување, максималната количина на вода достапна за растенијата, нормализиран индекс за разлика на вегетацијата, принос на зрно.*