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Research Article

STUDY OF SOIL MOISTURE DEPLETION PATTERN OF WHEAT WITH DIFFERENT IRRIGATION SCHEDULE

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Abstract- The present investigation was carried out to study on soil moisture depletion pattern of wheat to different irrigation scheduling. The experiment was conducted during the period from November to April in 2016-17 and 2017-18 in the experiment field of Research Farm at BSP (Soybean) unit, Department of Physics and Agro-meteorology, College of Agricultural Engineering, J.N.K.V.V, Jabalpur (M.P.).The experiment was laid out in Double Split Plot Design with three replication. Main treatment: Sowing date (3 levels at 15 days interval): D1: 30 November; D2: 15 December; D3: 30 December. Sub plot treatment: Varieties (2 varieties used): V1: GW-366 and V2: MP1202. Sub-sub plot treatment: Irrigation (3 levels): I1: crown root initiation +flowering stage; I2: crown root initiation + late jointing +milking stage; I3: crown root initiation+ tillering+ flowering+ milking stage. Soil moisture depletion pattern of wheat varieties are not showing differently as for as moisture use is concerned. Irrigation level I3 was always registered greater moisture content throughout the growing period with significant over other two, but (I2) can save irrigation water with only marginal yield reduction compared to (I3) irrigation treatment. The results showed that in treatment (I2) favorable soil moisture was maintained and optimum water productivity and yield of wheat was recorded with marginal reduction in yield and save water as compared to (I3).

Keywords- *Soil moisture depletion pattern, Water productivity, Crop yield*

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Introduction

Globally, India ranks first with 13.9 percent share in world's wheat area, while in terms of production, it stands second after China with almost 39 percent lesser production and productivity lag of about 52 percent [1]. Both the increase in crop yield and reduction in water consumption through improvement in basin efficiency contribute to the increase in water productivity [2]. In Madhya Pradesh, it is cultivated in 5.3 m ha of land with an annual production of 13.13 m tonne and productivity of 2.48 t ha^{-1} [3]. The average annual water availability of India is assessed as 1869 billion cubic meters (BCM), while the average annual rainfall of India is 1190 mm[4]. The major increase in the productivity of wheat has been observed in the state of Haryana, Punjab and U.P. Higher area coverage is reported from Madhya Pradesh in recent years. There is an increase in water demand whereas per capita availability of water for irrigation is falling. Optimization of water use is fundamental to water resource use. Substantial increase in water use efficiency (WUE) may be achieved by providing an optimal growth environment throughout the season. Understanding the effect of water stress on yield becomes an essential step for planning a suitable irrigation strategy for wheat. Water resources of India are limited in relation to the needs and hence available water has to be used in the most efficient manner. Irrigation is one of the most important inputs to increase crop yields in arid and semiarid regions. Irrigated agriculture accounts for 20% of the total cultivated land but contributes 40% of the total food produced worldwide [5]. Greater understanding of the impacts of irrigation timing in wheat (*Triticum aestivum* L.) promotes better irrigation management, which optimizes the positive and minimizes the negative impacts on yield and quality. Irrigation sector with almost 78 percent share dominates the present and future water use scenario in India [6]. One of the main response to these emerging challenges is to focus on improving water productivity in agriculture, as even small improvements could have large implications for local and national water budgets and allocation policies. This view is shared by Global Water Partnership [7-10].

The famous slogan of 'More Crop per Drop' [11] or 'Per Drop More Crop' as rechristened by the Indian Prime Minister featured throughout the past decade in analyses of water productivity of crops, cropping systems and agricultural production systems [12-14]. The current focus of water productivity has evolved to include the benefits and costs of water used for agriculture in terrestrial and aquatic ecosystems [15]. The deficit irrigation is a tool for scheduling the use of a limited water supply and in setting priorities among several irrigated crops. On the basis of the relationship between crop yield and water applied, it is possible to optimize the application of available irrigation water. Currently in Madhya Pradesh, an increase in irrigated area also increase in the acreage of wheat crop. The state has nearly 40% of total cropped area under rainfed and deprived of assured irrigation [16]. Considering lower availability of water during *rabi* season with less amount of rainfall distribution during this season, a proper management of irrigation water is most important to sustain productivity. Therefore, proper understanding of the effect of water stress on yield becomes an essential step for planning a suitable irrigation strategy for wheat crop. Grain yield and its components of wheat declined when exposed to drought stress condition [17]. Too early sowing makes plant weak having poor root system. In late sowing condition, wheat crop experiences high temperature stress. Late sowing checked the yield, caused by decline in the yield contributing traits like number of grains spike-1 and grain yield [18]. Normal sowing gave higher grain yield than late sowing [19]. Adequate soil moisture is required for the normal development of wheat plant at all the stages of growth. Optimum level of moisture requirement may, however, vary with stage of the growth. There is a lot of gain in use of drip and sprinkler system in order to use water appropriately and a proper time, however looking to large area under gravity irrigation using surface water distribution system; it is inevitable to use irrigation at different stages and with different quantity.

Materials and Methods

Site description

The study was conducted at Research Farm BSP (Soybean) unit, Department of Physics and Agro-Meteorology, College of Agricultural Engineering, J.N.K.V.V, Jabalpur (M.P.). The field experiment was carried out for two consecutive years during the rabiseasons of 2016-17 and 2017-18 at Research Farm, Department of Physics and Agro-meteorology, College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) which is situated at 230 09' North latitude and 790 58'East longitude and at an altitude of 411m above mean sea level.

Weather

The mean annual rainfall of Jabalpur based for last 20 years is 1350 mm which is mostly received from south-west monsoon between mid June to end of September with little occasional rainfall of 67.9 mm during other months. The mean monthly minimum temperature varies between 5.3 to 6.1°C in December and January which are the coldest month of the year and maximum temperature varies between 40 to 40.2°C during May and June respectively. Generally, relative humidity remains very low during summer (20 to 23%); moderate (60 to 75%) during winter and it attains high value (80 to 95%) during rainy season. The ideal temperature range for ideal germination of wheat seed is 20°C to 25°C though the seed can germinate in the temperature range 3.5 to 35°C. It is evident from the data that weather conditions were almost similar and favorable in both the years of investigation for the growth and development of wheat crop. During the growing months of crop (Nov to April of both year), maximum temperature of 39.7°C in season 2016-17 and 38.0°C in season 2017-18 were recorded in month of April (at harvest). Similarly, minimum temperature of 8.2°C and 6.0°C were recorded in month of November of year 2016 and 2017 respectively. Relative humidity was recorded maximum in winter season. It was recorded maximum value of 95% and 89% in month of November of both years. Wheat crop received rainfall of 71.2 mm in growing season of year 2016-17 and 33.8 mm in growing season of year 2017-18 which had beneficial effect on crop growth but it may affect the treatment effect and finally significance level of treatments in analysis. Weather information of Jabalpur (week-wise) during the entire crop growth of the year 2016-17 and 2017-18 as shown in [Fig-1] and [Fig-2] respectively.

Soil

The soil of the Jabalpur region is broadly classified as vertisol as per norms of U.S. classification. It has medium to deep depth and black in color. Soil samples were collected from 10 places at different depth with the help of soil auger before fertilizers application in the field. The samples were placed in an oven at 105°C for 24 hours for drying. The dried samples were re-weighed in an electrical balance and the difference was recorded. Bulk density of soil was determined using core cutter, the average bulk density was found to be 1.47 g/cm^3. The bulk density of soil was determined by using following formula

$$BD = M/V \quad \text{....... (eq. 1)}$$

$$V = \pi D^2/4 \times XL \quad \text{....... (eq. 2)}$$

Where

BD = Soil bulk density (g/cc); M = Dry soil mass in the core cutter (g);

V = Volume of cylindrical core cutter (cm^3); D = Diameter of cylindrical core cutter (cm); L = Length of cylindrical core cutter (cm).

Experimental details

The main plot treatments are sowing dates- (D)-D1:30th November, D2:15th December, D3:30th December. Sub plot treatments: Varieties- (V) - V1:GW 366, V2:MP 1202.Sub- sub plot treatment: Irrigation schedules- (I) -I1:Two irrigations (at CRI + flowering stage), I2:Three irrigations (at CRI + late jointing stage + milk stage), I3:Four irrigations (at CRI + tillering + flowering stage +milk stage). The experiment was laid out in a double split plot design results from a specialized randomization scheme for a factorial experiment with three replications. The crop was sown at the rate of 100 kg seed/ha manually in 20 cm apart from row to row. The plots were fertilized at the rate of 120:60:40 (N: P: K) kg ha^{-1} half the dose of nitrogen and the entire quantity of phosphorus and potash were applied as a basal dose before seed sowing. The rest half of the dose of nitrogen in the form of urea was applied subsequent to irrigation at crown root initiation stage. All agronornic practices were carried out uniformly for all treatments.

Details of Irrigation facilities

A tube well having discharge of the 2.5 lps is the main source of water. The discharge of irrigation water from pipe flow was measured by volumetric method. The flow was diverted into a suitable container, and the time to fill was measured. Discharge of pipe flow was determined. Wheat crop was irrigated through surface irrigation, where water is applied and distributed over the soil surface by gravity. Wheat crop was irrigated through surface irrigation, where water is applied and distributed over the soil surface by gravity. Bund is formed in all four sides of plot so the water is applied rapidly to the entire basin and is allowed to infiltrate. Basin irrigation is favored in soils with relatively low infiltration rates. Time required to apply net irrigation depth of 60 mm, was found 8 minute per plot of 20 m^2. Pre-sown irrigation was applied for wheat crop during 2016-17 and 2017-18. A common irrigation at CRI stage was applied in all the treatments on 22nd December, 2016 and 20th December, 2017 on the first date of sowing. Similarly, in second and third date, a common irrigation at CRI stage was applied in all the treatments on 9th January, 2017 and 2018.

Soil Moisture depletion studies

Field soils are generally at water contents between the field capacity (FC) and wilting point (WP). Soil moisture samples were taken from 0-15 and 15 -30 cm soil depth with the help of screw auger before sowing to till after harvesting at weekly interval throughout at each growing season or before irrigation and after irrigation of the crop in each treatment to observe the moisture depletion pattern. The moisture percentages obtained were used to calculate the consumptive use of water. At the end with the help of graph it was observed that soil moisture depletion patterns up or down in each treatment.

Water productivity

Water applied per irrigation was recorded and number of irrigations was counted and also rainfall amount was recorded throughout experiment period.

The yield of crop was assessed through yield observations. Water productivity terms play a crucial role in modern agriculture which aims to increase yield production per unit of water used, both under rainfed and irrigated condition. This can be achieved either by-

A. Increasing the marketable yield of the crops for each unit of water transpired.

Reducing the outflow / losses. B. Enhancing the effective use of rainfall, of the marginal quality water. C. Water productivity is defined as crop production 'per unit amount of water used[11].

Statistical analysis and interpretation of results

Data collected during the course of this study were statistically analyzed using variance analysis of a split-split plot design is divided into three parts: the main-plot, subplot and sub-subplot analysis. Data were analyzed using the GML procedure of SAS after testing for homogeneity of variance [20] and subjected to Analysis of variance (ANOVA), and means were separated using the LSD test. Critical difference at 0.05 probability level was worked out to compare the treatments suggested by [21].

Results

Field capacity of soil

Field capacity is defined as water quantity which a certain, initially saturated soil still able to hold against gravity after 2-3 days. The observation was taken after 24, 48, 72 and 96 hours of irrigation which shown in [Fig-3]. Soil samples were drawn with the help of screw auger in the experimental field. The field observations for determination of field capacity for 0 to 30 cm depth were recorded for each 15 cm depth. Upper 15 cm layer has a field capacity of 32.8 to 19.0 percent varying from 24 to 96 hrs after saturation. It varies from 35.7 to 21.7 percent in lower layer i.e. 15-30 cm depth. The average field capacity of the soil for 0 to 30 cm depth is found to be 27.3 percent.

Bulk density

Bulk density of soil was determined using core cutter method. The diameter and length of core cutter was 10 cm and 13 cm respectively, the average bulk density was found to be 1.47 g/cm^3.

Scheduling of irrigation

Uniform irrigation was given immediately after sowing to all the treatments for better establishment of the crop. A fixed quantity of 60 mm of water was applied to the experimental plots according to the irrigation schedules of the respective treatment. The schedule of irrigation followed for both the years of experimentation is given in [Table-1] and [Table-2].

I1: Two irrigation one each at CRI and flowering stage.

I2:Three irrigation one each at CRI, late jointing stage and milk stage.

I3:Four irrigation one each at CRI, tillering stage, flowering stage and milk stage.

Soil moisture depletion

Data pertaining to soil moisture as influenced by sowing dates, varieties and irrigation schedules are presented in [Table-3]. Soil moisture was observed at weekly interval during both the years of experimentations. Soil moisture differed with no significant difference under different sowing dates during first year of experimentations, while during second year and average of two years values varied significantly between D2 and D3, whereas difference between D1 and D2 shown non-significant. None of the variety showed significant differences in soil moisture during both the years and average of two years. Amongst the irrigation schedules, there is a significant difference in soil moisture among both the years and average of two years.

Table-1 Irrigation schedule and water applied under different irrigation treatments (2016-17)

Date of irrigation			Days after planting	Depth of water applied for Irrigation treatments (mm)		
Year	Month	Date		I1	I2	I3
1st date of planting (30/11/2016)						
2016	Nov	30	0	60	60	60
2016	Dec	22	22	60	60	60
2017	Jan	2	33	0	0	60
2017	Jan	28	59	0	60	0
2017	Feb	14	76	60	0	60
2017	March	4	94	0	60	60
No. of irrigation				3	4	5
Depth of Irrigation (mm)				180	240	300
Rainfall (mm)				71.2	71.2	71.2
Total depth of water used				251.2	311.2	371.2
2nd date of planting (15/12/2016)						
2016	Dec	15	0	60	60	60
2017	Jan	9	25	60	60	60
2017	Jan	19	35	0	0	60
2017	Feb	12	59	0	60	0
2017	Mar	4	79	60	0	60
2017	Mar	22	97	0	60	60
No. of irrigation				3	4	5
Depth of Irrigation (mm)				180	240	300
Rainfall (mm)				62.4	62.4	62.4
Total depth of water used				242.4	302.4	362.4
3rd date of planting (30/12/2016)						
2016	Dec	30	0	60	60	60
2017	Jan	20	21	60	60	60
2017	Jan	31	32	0	0	60
2017	Feb	25	57	0	60	0
2017	Mar	17	77	60	0	60
2017	Mar	30	90	0	60	60
No. of irrigation				3	4	5
Depth of Irrigation (mm)				180	240	300
Rainfall (mm)				62.4	62.4	62.4
Total depth of water used				242.4	302.4	362.4

Table-2 Irrigation schedule and water applied under different irrigation treatments (2017-18)

Date of irrigation			Days After planting	Depth of Irrigation (mm)		
Year	Month	Date		I1	I2	I3
1st date of planting (30/11/2017)						
2017	Nov	30	0	60	60	60
2017	Dec	20	21	60	60	60
2018	Jan	3	35	0	0	60
2018	Jan	26	58	0	60	0
2018	Feb	19	82	60	0	60
2018	March	8	98	0	60	60
No. of irrigation				3	4	5
Depth of Irrigation (mm)				180	240	300
Rainfall (mm)				33.8	33.8	33.8
Total depth of water used				213.8	273.8	333.8
2nd date of planting (15/12/2017)						
2017	Dec	15	0	60	60	60
2018	Jan	9	25	60	60	60
2018	Jan	17	33	0	0	60
2018	Feb	10	58	0	60	0
2018	Mar	8	84	60	0	60
2018	Mar	20	96	0	60	60
No. of irrigation				3	4	5
Depth of Irrigation (mm)				180	240	300
Rainfall (mm)				33.8	33.8	33.8
Total depth of water used				213.8	273.8	333.8
3rd date of planting (30/12/2017)						
2017	Dec	30	0	60	60	60
2018	Jan	18	19	60	60	60
2018	Feb	1	33	0	0	60
2018	Feb	23	55	0	60	0
2018	Mar	15	75	60	0	60
2018	Mar	29	89	0	60	60
No. of irrigation				3	4	5
Depth of Irrigation (mm)				180	240	300
Rainfall (mm)				33.8	33.8	33.8
Total depth of water used				213.8	273.8	333.8

Table-3 Soil moisture content (%) influenced by sowing dates, varieties and irrigation schedules

Treatment	Soil Moisture content (%) at weekly interval		
	2016-17	2017-18	Pooled
Sowing dates			
D1- 30 Nov	19.0	19.0	19.0
D2- 15 Dec	19.0	19.0	19.0
D3- 30 Dec	19.0	20.0	19.5
SEm±	0.02	0.02	0.02
LSD (p=0.05)	0.09	0.07	0.08
Varieties			
V1- GW 366	19.0	19.0	19.0
V2- MP-1202	19.0	19.0	19.0
SEm±	0.01	0.01	0.01
LSD (p=0.05)	0.04	0.05	0.05
Irrigation Schedules			
I1-CRI+FL	18.0	18.0	18.0
I2-CRI+ LJ+ ML	19.0	20.0	19.5
I3-CRI+ TL+ FL+ ML	20.0	20.0	20.0
SEm±	0.02	0.02	0.02
LSD (p=0.05)	0.06	0.07	0.07

CRI- Crown root initiation, LJ- Late jointing, TL-Tillering, FL- Flowering, ML-Milking

Treatment having four irrigations at critical stages recorded significantly highest soil moisture (20 %) than rest of the irrigations schedules during both the years and average of the two years. Soil moisture (%) at weekly interval comparing with three different dates of sowing, two different wheat varieties and three different irrigation level as shown in figure 5 to 10 for both years. Soil moisture depletion pattern compare with dates 30th November raised highest soil moisture content up to 23 % in 2016-17 and 30th December raised the highest soil moisture content up to 24% in 2017-18, when soil moisture was taken as at 0-15 and 15-30 cm.

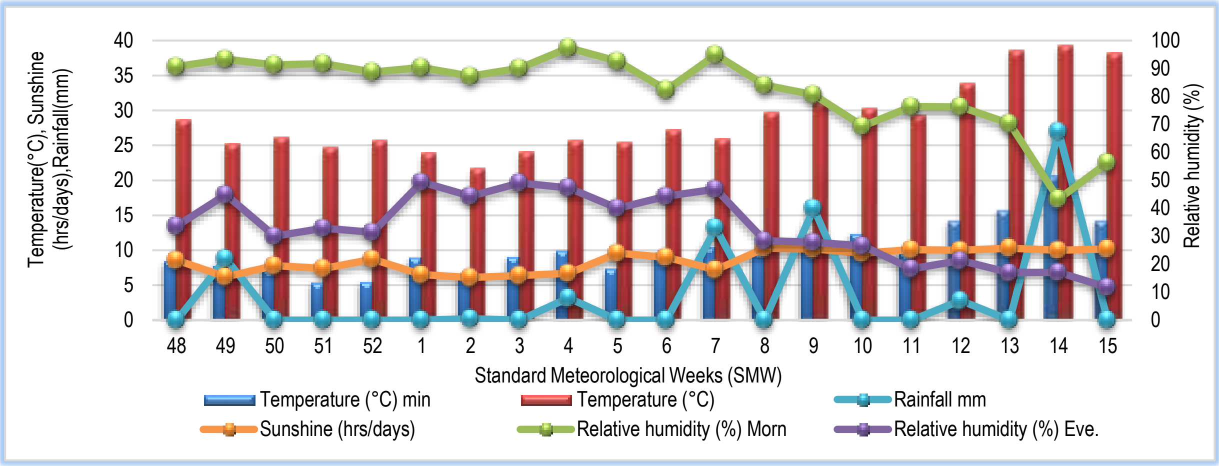

Fig-1 Weather information of Jabalpur (week-wise) during the entire crop growth of the year 2016-17

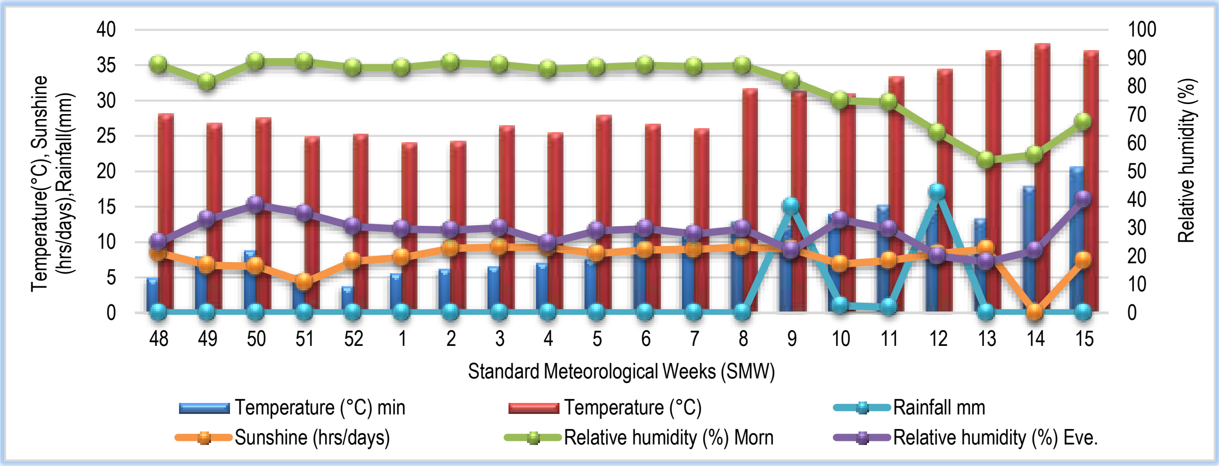

Fig-2 Weather information of Jabalpur (week-wise) during the entire crop growth of the year 2017-18

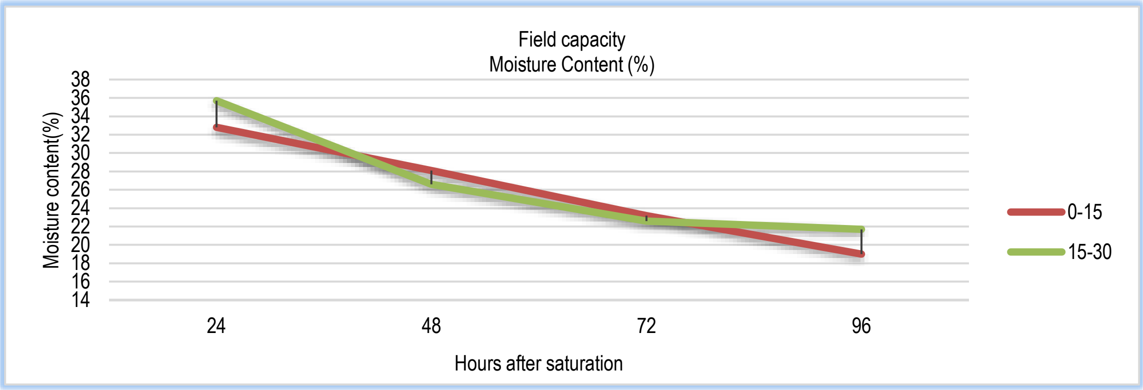

Fig-3 Moisture content variation with time after saturation

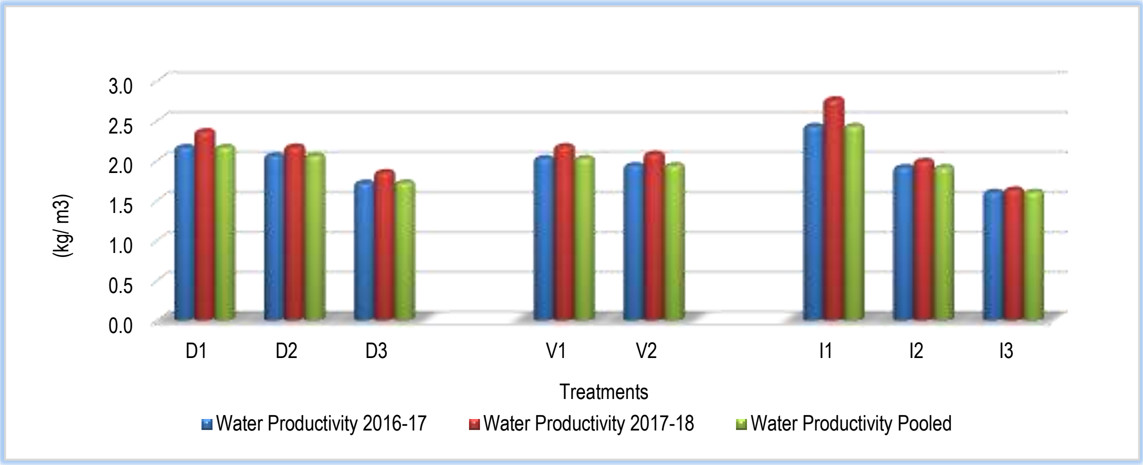

Fig-4 Water productivity of wheat as influenced under various treatments

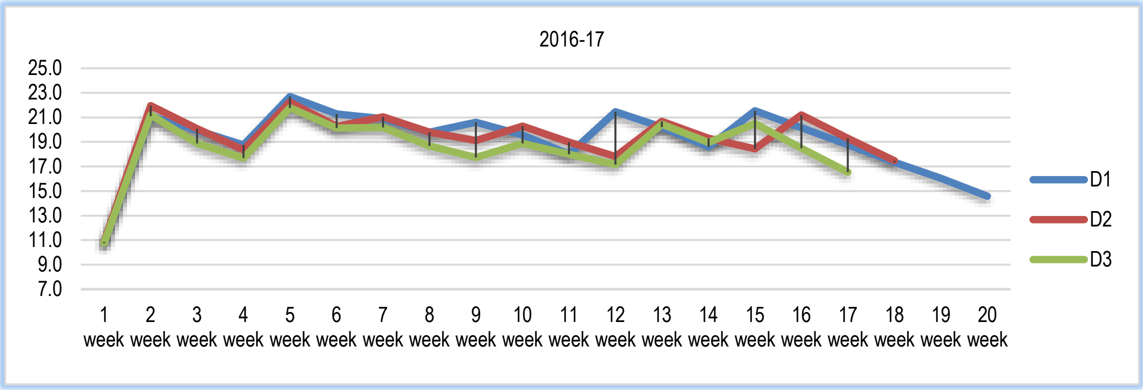

Fig-5 Soil moisture (%) at weekly interval comparing with three different dates of sowing

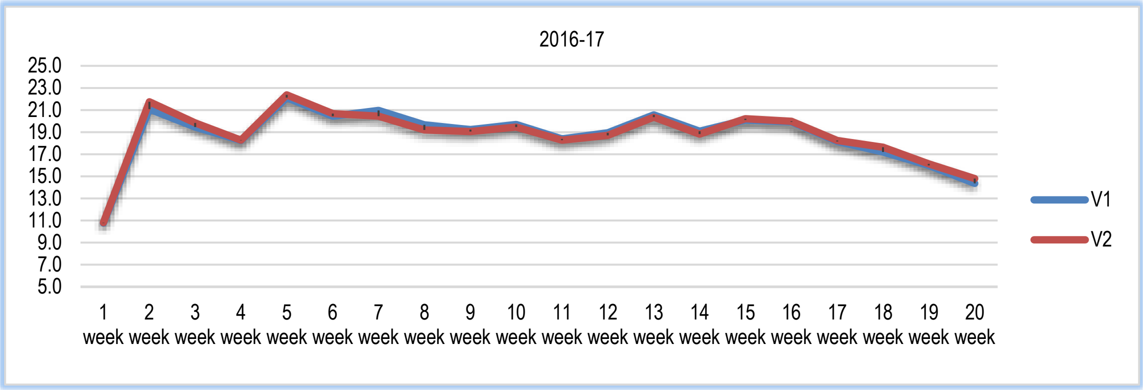

Fig-6 Soil moisture (%) at weekly interval comparing with two wheat crop varieties

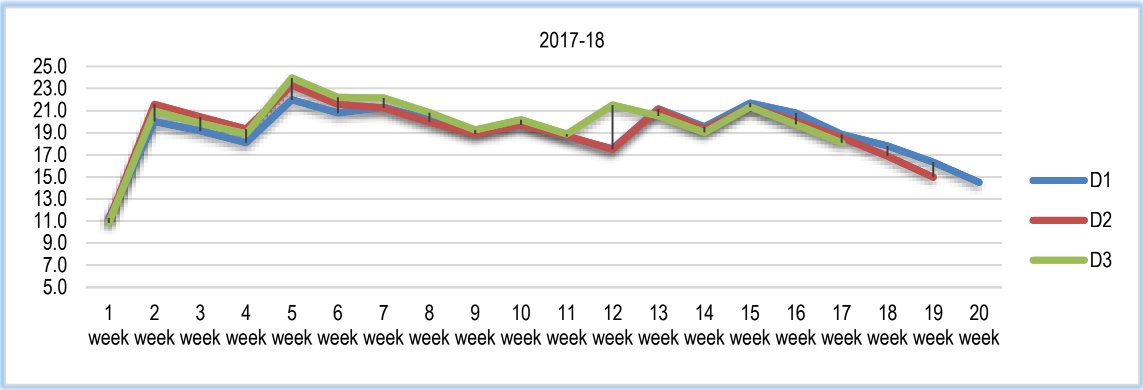

Fig-7 Soil moisture (%) at weekly interval comparing with three different dates of sowing

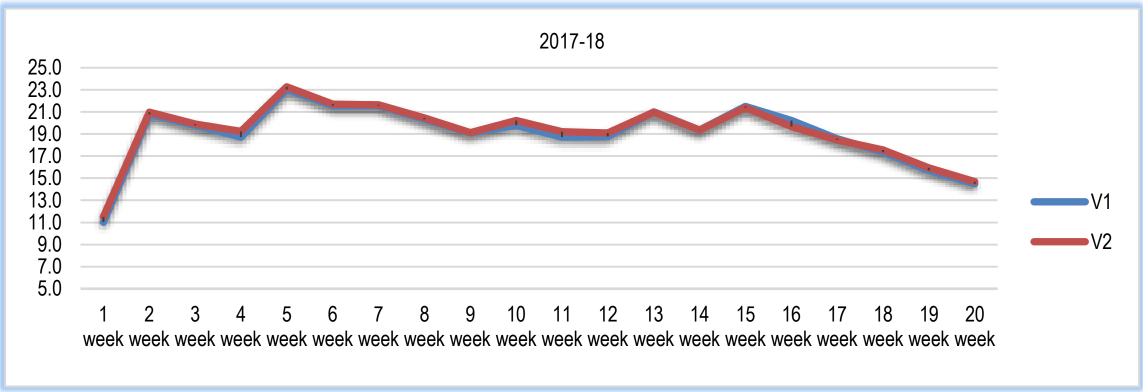

Fig-8 Soil moisture (%) at weekly interval comparing with two wheat crop varieties

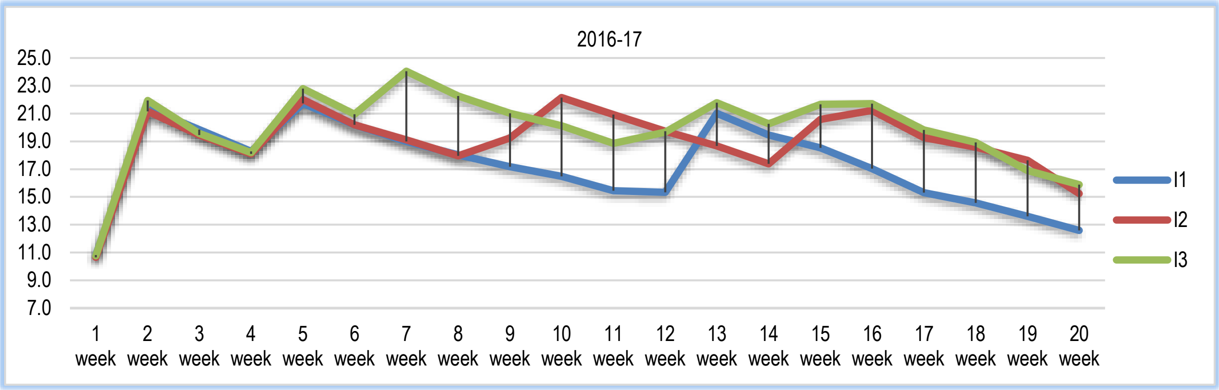

Fig-9 Soil moisture (%) at weekly interval comparing with three level of irrigation schedule

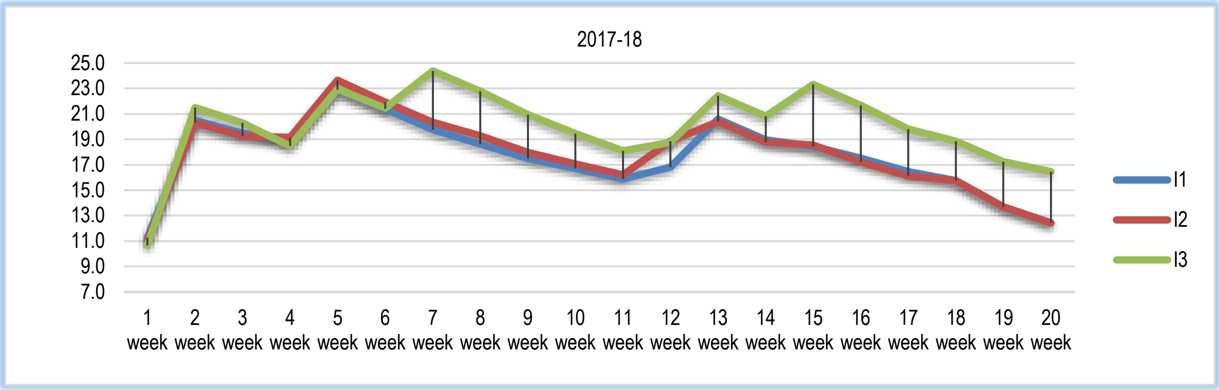

Fig-10 Soil moisture (%) at weekly interval comparing with three level of irrigation schedule

Table-4 Grain yield, Straw yield, total biomass yield and water productivity as influenced by sowing dates, varieties and irrigation schedules

Treatment	Grain Yeild (Kg ha^{-1})			Straw Yeild(Kg ha^{-1})			Water productivity (kg/m^3)		
	2016-17	2017-18	pooled	2016-17	2017-18	pooled	2016-17	2017-18	Pooled
Planting dates									
D1- 30 Nov	5255.7	4815	5035.5	8613.0	8189.0	8401.0	2.2	2.4	2.3
D2- 15 Dec	4827.5	4423	4625.1	8095.0	7822.8	7958.9	2.1	2.2	2.1
D3- 30 Dec	4026.7	3970	3998.4	7193.0	7149.5	7171.3	1.7	1.9	1.8
SEm±	30.05	27.96	29.0	110.21	101.5	105.9	0.01	0.02	0.02
LSD (p=0.05)	117.98	109.79	113.9	432.75	398.7	415.7	0.04	0.07	0.06
Varieties									
V1- GW 366	4809.3	4518	4663.9	8107.4	7871	7989.3	2.0	2.2	2.1
V2- MP-1202	4597.2	4287	4442.1	7826.6	7570	7698.1	1.9	2.1	2.0
SEm±	33.87	37.81	35.8	76.06	94.96	85.5	0.01	0.02	0.02
LSD (p=0.05)	117.20	130.83	124.0	263.22	328.61	295.9	0.05	0.08	0.07
Irrigation Schedules									
I1-CRI+FL	4510.5	4233	4371.6	7307.2	7327	7317.0	2.4	2.8	2.6
I2-CRI+ LJ+ ML	4699.2	4409	4554.2	8070.2	8077	8073.5	1.9	2.1	2.0
I3-CRI+ TL+ FL+ ML	4900.2	4566	4733.2	8523.7	7758	8140.7	1.6	1.7	1.7
SEm±	34.66	45.44	40.1	135.51	130.62	133.1	0.01	0.03	0.02
LSD (p=0.05)	101.17	132.64	116.9	395.52	381.25	388.4	0.04	0.08	0.06

A close look of [Fig-6] and [Fig-8] depicts identified pattern of moisture depletion in both the varieties in both years, *i.e.*, varieties are not showing differently as for as moisture use is concerned. Irrigation level I3 was always registered greater moisture content throughout the growing period with significant over other two ([Fig-9] and [Fig-10]. In 2016-17 I3 highest soil moisture content found in 7th week (SMW) 24% and lowest 15.9% in 20th week (SMW) and in 2017-18 I3 highest soil moisture content found in 7th week (SMW) 24.4% and lowest 16.5% in 20th week (SMW).

Water Productivity

Data on water productivity as influenced by sowing dates; varieties and irrigation schedules are presented in [Table-4]. Water productivity varied significantly under different sowing dates during both the years of experimentation and average of two years. The crop sown on 30th Nov. recorded significantly higher water productivity (2.2 and 2.4) than 15th Dec. and 30th Dec. sowing during both the years and average of two years. The significantly higher water productivity (2.0 and 2.2) was noted in variety GW 366 during both the years and average of the years. Amongst the irrigation schedules, two irrigations (CRI+FL) recorded significantly higher water productivity (2.4 and 2.8) than rest of the irrigations schedules during both the years of experimentations and average of the years. The lowest water productivity (1.6) was noted with four irrigation (CRI+ TL+ FL+ ML) treatment as shown in [Fig-4].

Conclusion

Favorable soil moisture was maintained in the irrigation scheduling treatments of (I3) crown root initiation+ tillering+ flowering+ milking stage, from 30 November sowing date with GW-366 variety recorded significantly highest grain yield as compared to rest of treatments with maintaining favorable soil moisture throughout growing period. Highest water productivity was recorded in treatment I1 in both years of experiment which may be due to lowest water use, followed by I2 and I3. However, soil moisture was inadequate in irrigation scheduling at (I1) crown root initiation + flowering. Whereas in irrigation scheduling treatments (I2) crown root initiation + late jointing +milking stage, soil moistures were slightly depleted below allowable limit.

Irrigation scheduling at (I2) can save irrigation water with only marginal yield reduction compared to (I3) irrigation treatment. Other irrigation scheduling treatments save the water, with a significant yield reduction. So that, (I2) practice can be an important and beneficial option to prevent crop yield reductions under water shortage. Irrigation scheduling at (I3) recorded significantly highest grain yield and found to be superior over rest of the treatments. Hence it may be concluded that in treatment (I2) favorable soil moisture was maintained, and optimum water productivity and yield of wheat was recorded with marginal reduction in yield and save water as compared to (I3).

Application of research: This research article highlights the impact of soil moisture depletion pattern, varieties, date of sowing, irrigation level and water productivity in wheat yield.

Research Category: Soil moisture depletion pattern

Abbreviations: %- Percentage, cm- Centimeter, m- meter, g- Gram,g/cm^3- gram per cubic centimeter, kg ha-1- kilogram per hectare, kg/m^3- killogram per cubic meter, mm- Millimeter, Tmax- Maximum temperature, Tmin- Minimum temperature, °C- Degree celcius, @- At the rate

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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: Research Farm BSP (Soybean) unit, Department of Physics and Agro-Meteorology, College of Agricultural Engineering, Jabalpur, 482004, India

Cultivar / Variety / Breed name: Wheat

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

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