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Research Article

GROWTH AND YIELD INFLUENCED BY WHEAT VARIETIES, ON DIFFERENT DATES AND IRRIGATION LEVELS

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Abstract: 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.) to find out the effect of irrigation under varying sowing dates on yield performance of wheat. The experiment was laid out in Double Split Plot Design with three replications. 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. The highest days to maturity was recorded from D1 while the lowest days to maturity was observed from D3. D1 recorded the highest length of ear head, grain per ear heads, weight of 1000 grains, grain yield, straw yield, biomass yield and harvest index respectively compared to D3. Within varieties less difference found, GW-366 variety produced higher results as compared to MP-1202 variety in length of ear head, grain per ear heads, weight of 1000 grains, grain yield, straw yield, biomass yield and harvest index. I3 produced the highest results than that of I1 in length of ear head, grain per ear heads, weight of 1000 grains, grain yield, straw yield, biomass yield and harvest index respectively. Better grain yield performance of wheat was obtained from 30 November sowing date with GW-366 variety and with irrigation crown root initiation+ tillering+ flowering+ milking stage.

Keywords: Grain yield, Straw yield, Biomass yield, Harvest index

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Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereals of the world on account of its wide adaptability to agro-climatic conditions and different soil. It is a major staple food for 35% of the world population and provides more calories and protein in the world's diet than any other crop [1]. Globally, it occupies an area of 221.1 M ha with an annual production of 697.8 M tonnes and the average productivity of 3.1 tonnes ha^{-1}. In India, wheat is grown over 30 M ha with a production of 94 M tonnes and contributing about 43% to the country's granary [2]. In M.P, it is cultivated in 5.3 M ha of land with an annual production of 13.13 M tonnes and productivity of 2.48 tonnes ha^{-1}.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 [3]. Winter in M.P. is characterized by large fluctuations in temperature and precipitation. In M.P., sowing of wheat starts from mid-November and ends by the third week of December based on different cropping system. Wheat is sown after harvesting of soybean during the month of December. [4] and [5] observed an increase in yield with early sowing, however yield decline with the delay in sowing. Currently in M.P, an increase in irrigated area also increases in the acreage of wheat crop however, state also have nearly 40% total cropped area under rainfed and deprived of assured irrigation [6]. 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. 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. The crop water need is related to moisture sensitive periods. All stages of crop growth are not uniformly susceptible to water scarcity. On the other hand, some stages can cope-up with water shortage very well, while others are more susceptible and water shortages at such stages may result indistinct yield losses. Crops grown on different dates experience water stress of different magnitudes. Consequently, results into different yields. Early sowing accelerates early plant growth and maximizes the plant's utilization of the growing season. The delay in sowing affects the yield components and other aspects of the growth and development. The 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 [7]. Present study is planned to observe the growth and yield of wheat when sown on different dates and its irrigation requirement used to irrigate at different stages.

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 *rabi* seasons 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.

Table-1 *Monthly Climatic normal during rabi season at Jabalpur (2016-17)*

Month	Relative humidity (%)	Tmax (°C)	Tmin(°C)	Sunshine hours (hr/day)	wind speed (km/hr)	Rainfall (mm)
November	95.0	29.1	8.2	8.7	1.3	0.0
December	91.0	25.7	8.4	7.6	1.9	0.3
January	91.3	23.8	8.6	6.7	2.8	0.1
February	87.5	27.6	9.7	9.2	2.9	0.5
March	74.1	32.7	13.0	9.9	3.4	0.6
April	48.0	39.7	18.7	10.1	5.4	1.2

Table-2 *Monthly Climatic normal during rabi season at Jabalpur (2017-18)*

Month	Relative humidity (%)	Tmax (°C)	Tmin(°C)	Sunshine hours (hr/day)	wind speed (km/hr)	Rainfall (mm)
November	89.0	28.8	6.0	8.7	1.9	0.0
December	86.5	26.2	6.4	6.5	2.5	0.0
January	87.0	25.1	6.5	8.9	2.4	0.0
February	87.1	28.2	11.4	8.9	2.3	0.0
March	77.9	31.1	12.9	8.4	3.5	0.6
April	60.0	38.0	19.3	7.9	5.8	0.0

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 6.1ºC in December and January which are the coldest month of the year and maximum temperature varies between 40 to 40.2ºC 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 20ºC to 25ºC though the seed can germinate in the temperature range 3.5 to 35ºC. 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 38.0ºC in season 2017- 18 were recorded in month of April (at harvest). Similarly, minimum temperature of 8.2ºC 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. The climatic normal were calculated from the monthly values of weather parameters as shown in [Table-1] and [Table-2].

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/cm3. The bulk density of soil was determined by using following formula

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

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

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); and

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-1half 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. 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. Plant population m^{-2}, plant height cm, no. of tillers m^{-2}, leaf area index, total dry matter, chlorophyll content (%) will be observed on 30,60,90 days after sowing and before harvesting.

The leaf area index was calculated from the sample plants taken for dry matter production studies. Leaf area was measured with leaf area meter (CI-203 model, CID Bio-Science, WA, USA). The green plants in 25 cm row length were uprooted and leaves were separated and their area was measured. Leaf area index is a dimensionless quantity that characterized plant canopies. It is defined as the one sided green leaf area per unit ground surface area. The following equation was used for calculation of leaf area index (LAI):

$$LAI = \frac{Total\ green\ leaf\ area\ of\ the\ plants\ (cm2)}{Total\ ground\ area\ (cm2)}$$

Post-harvest observation-Length of ear head, Number of grains per ear head, 1000-grain weight, Grain and straw yield, Harvest Index.

Harvest index refers to the ratio of economic yield (seed yield) to the biological yield (seed + straw yield) and it is expressed under a particular treatment in percentage. It was worked for each plot by using the following formula [8].

$$Harvest\ Index = \frac{Economic\ Yield}{Biological\ Yield} \times 100$$

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 [9] 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 [10].

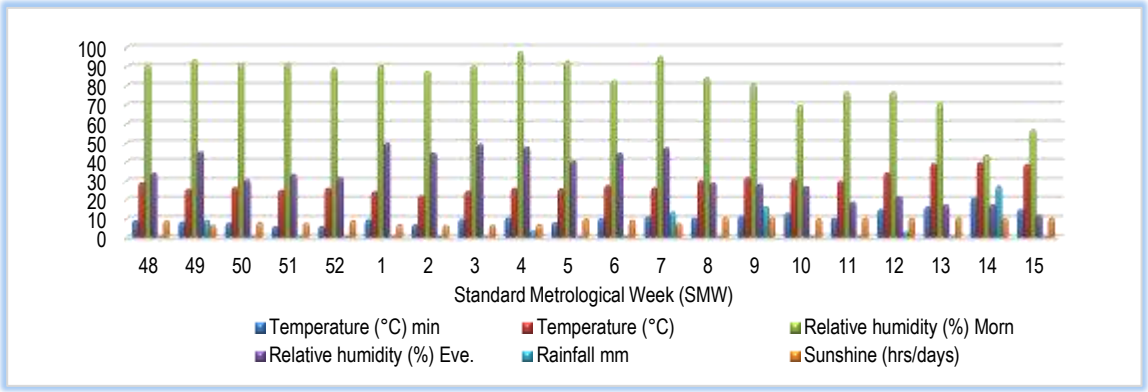

Fig-1 Meteorological information of Jabalpur (week-wise) during the entire crop season of the year 2016-17

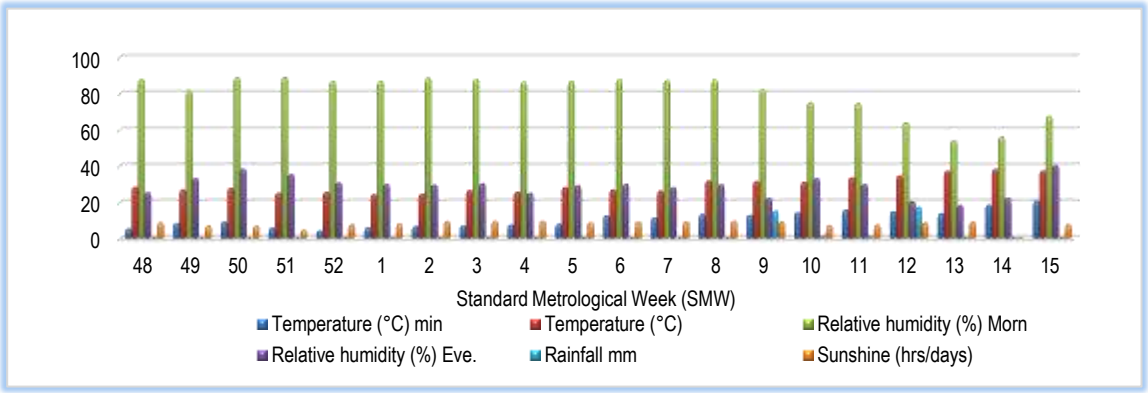

Fig-2 Meteorological information of Jabalpur (week-wise) during the entire crop season of the year 2017-18

Table-3 *Irrigation dates and depth (mm) for experimental trial in 2016-17*

Date of irrigation			Days after	Depth of Irrigation (mm)		
Year	Month	Date	planting	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-4 *Irrigation dates and depth (mm) and for experimental trial in 2017-18*

Date of irrigation			Days after	Depth of Irrigation (mm)		
Year	Month	Date	planting	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

The weekly maximum temperature during crop season of the year 2016-17 varied from 21.7˚C SMW 2 to 39.3˚C SMW 14 while during the year 2017-18, it varied from 24.0˚C SMW 1 to 38.0˚C SMW 14 and minimum temperature varied from 5.5˚C SMW 51 to 20.6˚C SMW 14 during 2016-17 and from 3.9˚C SMW 52 to 20.6˚C SMW 15 in the crop season 2017-18. The maximum temperature was higher during 2016-17 and lower minimum temperature prevailed during the middle of the crop period during 2017-18. The weekly distributions of rainfall and relative humidity during the crop periods are shown in [Fig-1] and [Fig-2]. The relative humidity (RH) varied from 11.7 SMW 15 to 97.4 SMW 4 percent in the first crop season. The relative humidity ranges from 18.0 SMW 13 to 88.7 SMW 51 and SMW 52 percent for second crop season. Total rainfall received was 71.2 mm and 33.8 mm distributed in 7 and 5 rainy days during first and second year respectively. The temporal distribution of rainfall and its amount were caused micro environment modification which may also be responsible for variation in crop growth and yield. The crop was exposed to total sunshine hours of 170.9 and 152.5hours during whole season in the first and second year, respectively.

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.

Growth parameters

Among the varieties, there is a significant difference in plant population among both the years suggesting a variation in the number of plants per plot. Similar is the results at different irrigation schedule among different stages of crop growth. Among sowing dates at 30 DAS, lesser plant height exhibited in D3 (30 December) date as compared to D2 (15 December) and D1 (30 November) sown dates significantly in both years and pooled data. Similar is the trend observed significantly at 60 and 90 DAS and at harvest, thereby suggesting plant height decrease with delay in sowing dates of wheat crop. Chlorophyll content of wheat increased up to 60 DAS and reduced marginally at 90 DAS. The treatments with four irrigations recorded significantly higher chlorophyll content than the others of scheduled irrigation. Leaf area index of wheat increased up to 60 DAS and reduced marginally at 90 DAS. Leaf area index was significantly higher under 30th Nov. sowing than to 15th Dec. (1.58 and 1.71) and 30th Dec. sowing (1.25 and 1.25) at 30 DAS during both the years and average over the years. Similar trend was observed at 60 DAS and 90 DAS during both the years and average of the two years. Effect of treatments on leaf area index on 30, 60 and 90 days after sowing (DAS) shown in [Fig-2].

Effect of yield and yield attributes

Yield attributes and yields of wheat crop influenced by sowing dates, varieties and irrigation schedule of both years and pooled data shown in Table 5 and Table 6 respectively. Lengths of ear head, it was directly showed the higher number of grains in panicle so that yield will be increased [11]. It was influenced significantly by the dates of sowing. The potentiality of these characters was restricted to a considerable extent when the crop was sown late. The 30 November sown crop produced ears of maximum length and minimum length showed by 30 December sown crop. It might be attributed due to the fact that when the crop was sown late, there would have been low temperature in the beginning but after February onward the temperature starts rising very fast and the plant do not get sufficient favorable environment to express their full potentiality. Such observations were also reported [12]. Number of grains earhead-1 significantly influenced by sowing time and it gradually decreased as sowing was delayed. It is influenced by environment particularly that of temperature prevailed during the time of sowing and vegetative and reproductive stages. Similar results were obtained [13]. Weight of 1000 grains (g) affected by environment specially that of temperature controlled during the time of vegetative and reproductive stages. It was highest in the crop sown on 30 November and decreased as sowing was delayed, therefore weight of 1000 grains was significantly affected by dates of sowing.

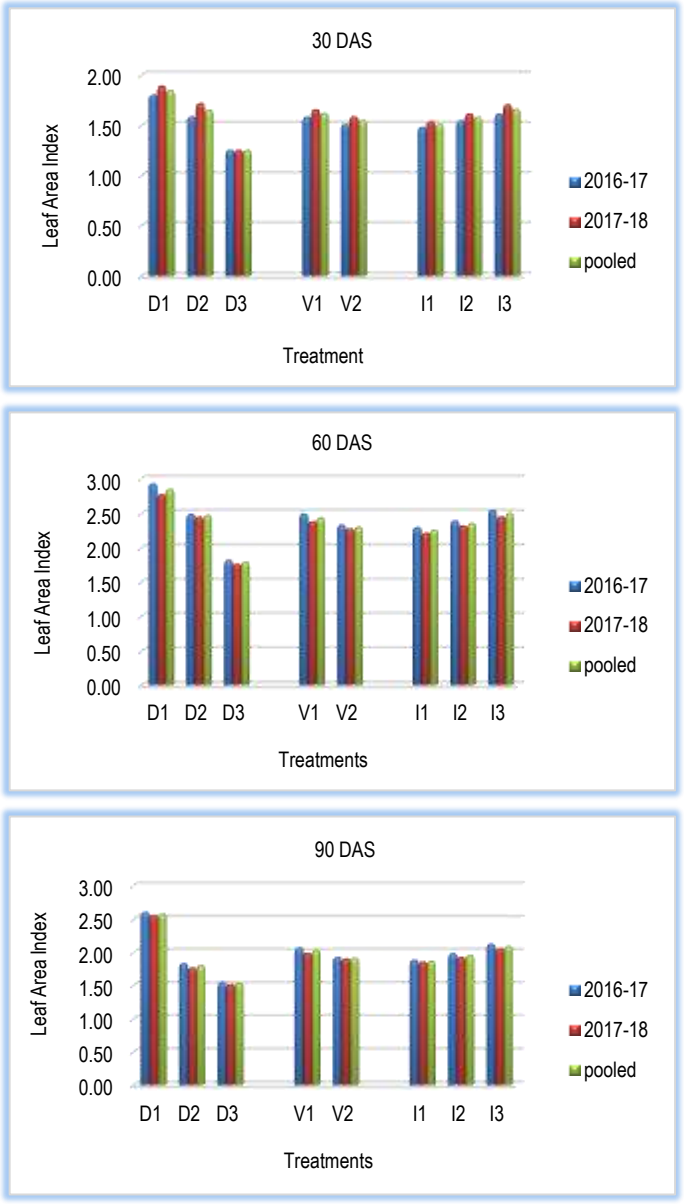

Fig-3 Effect of treatments on leaf area index on 30, 60 and 90 days after sowing (DAS)

Sudden rise in temperature with hot wind, the grains were forced to mature and dry, this might be due to the fact that under later sown conditions. Hence, the grains obtained from 30 November sown crop resulted in higher test weight, the timely sown crop gets an advantage because after having completed its vegetative growth satisfactory it comes in the earing stage when the temperature is quite favorable. Similar findings and stated that timely sowing gave higher test weight as compared to delayed sowing [14]. On the other hand the late sown crop obtained the immature grains which remain in the milk stage during the period of high temperature. Total biomass yield, grain yield, straw yield, and harvest index significantly affected by sowing dates during both year of experimentation and average of the years. The crop sown on 30thNovember was significantly higher in all the aspects of yield over delayed sown crop on 15th and 30th December. Under late sown conditions the yield loss due to high temperature is also reported [15] due to heat stress. The early sown crop, on the other hand, having favorable cool weather conditions for longer duration recorded better growth and yield attributes resulted in greater productivity. Similar results were obtained by, [16] and [13]. Effect of treatments on yield attributes and yields of wheat crop shown in [Fig-3] and [Fig-4] respectively.

Table-5 *Yield attributes of wheat as influenced by sowing dates, varieties and irrigation schedule*

Treatment	Length of Earhead (cm)			Grain /Earheads(No.)			Weight of 1000 grains(g)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Planting dates									
D1- 30 Nov	8.86	8.58	8.72	47.3	46.6	46.92	52.2	47.6	49.89
D2- 15 Dec	8.66	8.29	8.47	45.8	41.9	43.85	48.1	43.3	45.72
D3- 30 Dec	8.22	7.38	7.8	40.9	39.7	40.29	41.6	41	41.27
SEm±	0.12	0.15	0.14	0.49	0.23	0.36	0.31	0.31	0.31
LSD (p=0.05)	0.48	0.59	0.54	1.91	0.91	1.41	1.22	1.21	1.22
Varieties									
V1- GW 366	8.72	8.25	8.48	45.34	43.47	44.41	48.27	44.97	46.62
V2- MP-1202	8.43	7.92	8.18	43.97	41.97	42.97	46.28	42.99	44.63
SEm±	0.1	0.09	0.09	0.37	0.21	0.29	0.19	0.23	0.21
LSD (p=0.05)	0.35	0.3	0.32	1.28	0.73	1	0.65	0.81	0.73
Irrigation Schedules									
I1-CRI+FL	8.29	7.85	8.07	43.47	40.98	42.23	45.07	42.35	43.71
I2-CRI+ LJ+ ML	8.38	8.09	8.24	44.43	42.67	43.55	47.52	43.92	45.72
I3-CRI+TL+FL+ML	9.06	8.31	8.68	46.07	44.5	45.28	49.23	45.67	47.45
SEm±	0.08	0.11	0.09	0.43	0.34	0.39	0.38	0.58	0.48
LSD (p=0.05)	0.23	0.32	0.27	1.26	0.99	1.12	1.12	1.68	1.4

Table-6 *Grain yield, Straw yield, total biomass yield and harvest index as influenced by sowing dates, varieties and irrigation schedules*

Treatment	Grain Yield (Kg ha-1)			Straw Yield(Kg ha-1)			Biomass yield (Kg ha-1)			Harvest index (Kg ha-1)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Sowing dates												
D1- 30 Nov	5255.7	4815.3	5035.5	8613.0	8189.0	8401.0	13868.7	13004.3	13436	38.0	37.0	37.5
D2- 15 Dec	4827.5	4422.7	4625.1	8095.0	7822.8	7958.9	12922.5	12245.5	12584	37.4	36.2	36.8
D3- 30 Dec	4026.7	3740.3	3883.5	7193.0	7379.3	7286.1	11219.7	11119.6	11170	35.9	33.8	34.9
SEm±	30.05	25.73	27.89	110.21	102.69	106.45	93.91	98.23	96.07	0.43	0.35	0.39
LSD (p=0.05)	117.98	101.03	109.50	432.75	403.21	417.98	368.73	385.71	377.22	1.69	1.37	1.53
Varieties												
V1- GW 366	4809.3	4418.1	4613.7	8107.4	7971.5	8039.5	12916.8	12389.6	12653	37.2	35.6	36.4
V2- MP-1202	4597.2	4234.1	4415.7	7826.6	7622.5	7724.5	12423.8	11856.6	12140	37.0	35.8	36.4
SEm±	33.87	38.63	36.25	76.06	85.54	80.80	67.82	105.96	86.89	0.35	0.26	0.30
LSD (p=0.05)	117.20	133.69	125.44	263.22	296.02	279.62	234.69	366.68	300.68	1.22	0.88	1.05
Irrigation Schedules												
I1-CRI+FL	4510.5	4251.1	4380.8	7307.2	7308.4	7307.8	11817.7	11559.4	11689	38.0	36.8	37.4
I2-CRI+ LJ+ ML	4699.2	4257.7	4478.4	8070.2	8228.3	8149.2	12769.3	12485.9	12628	36.8	34.0	35.4
I3-CRI+ TL+ FL+ ML	4900.2	4469.6	4684.9	8523.7	7854.4	8189.0	13423.8	12323.9	12874	36.5	36.2	36.4
SEm±	34.66	45.86	40.26	135.51	127.01	131.26	123.37	120.32	121.85	0.52	0.51	0.52
LSD (p=0.05)	101.17	133.86	117.51	395.52	370.71	383.11	360.10	351.20	355.65	1.52	1.50	1.51

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

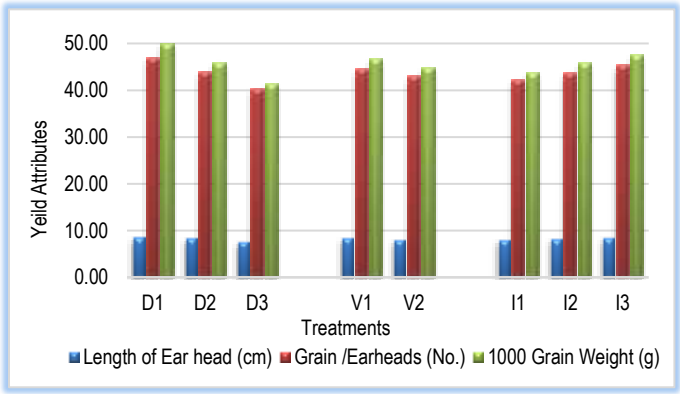

Fig-4 Effect of treatments on yield attributes of wheat crop

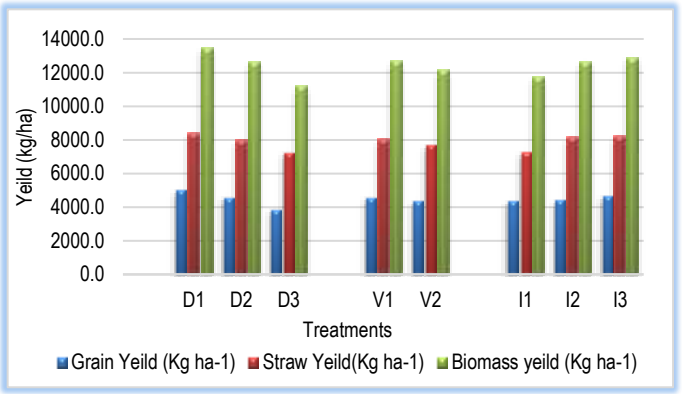

Fig-5 Effect of treatments on yields of wheat crop

The interaction table is mentioned in [Table-7]. The overall interaction of both the years exhibited 30 Nov (D1) produce more grain yield than the remaining sown dates in both the varieties. Similarly, 15 Dec (D2) sown dates in MP-1202 variety also exhibited a non significant difference with 30 Nov (D1) sown dates in grain yield. Among irrigation levels, I3 irrigation performed higher grain yield than the other irrigation levels in both the varieties. However, I2 level exhibited non significant difference with I3 levels in D1 and D2 sown dates, respectively. The treatment combination D1I3V1 and D1I3V2 recorded significantly highest grain yield (5411 and 4992) respectively over rest of the treatment combinations which was followed by D1I2V1 and D1I2V2 (5206 and 4839) during experimentations period. The variety GW 366 was significantly superior in producing the entire yield over MP 1202.

This might be due to genetic makeup of that particular variety. The similar result among the varieties [16,18]. Overall interaction (both years) between sowing dates, varieties and irrigation levels of grain yield (kg/ha) is presented in [Table-7]. The yield of crop sown on 15 Dec (D2) and 30 Dec (D3) in GW-366 variety are 8.5% and 21.6 % lower than crop sown on 30 Nov (D1) respectively in first level of irrigation (I1- CRI+FL). Similarly on 15 Dec (D2) and 30 Dec (D3) in I2 (CRI+ LJ+ ML) 11% and 36.6 % and I3 (CRI+TL+FL+ML) 9% and 26% lower than crop sown on 30 Nov (D1) respectively. Whereas in MP-1202 variety the yield of crop sown on 15 Dec (D2) and 30 Dec (D3) are 11% and 27 % lower than crop sown on 30 Nov (D1) respectively in first level of irrigation (I1- CRI+FL). On 15 Dec (D2) and 30 Dec (D3) in I2 (CRI+ LJ+ ML) 5.8 % and 19 % and I3 (CRI+TL+FL+ML) 5.7% and 25% lower than crop sown on 30 Nov (D1) respectively.

The irrigation schedule at critical stages (*i.e.*, CRI+TL+FL+ML) with first date of sowing of wheat crop is very essential as it directly impact the grain yield to increase 25 to 26 %.

Table-7 Overall interaction between sowing dates, varieties and irrigation levels of grain yield (kg/ha)

Overall interaction	I1	I2	I3
D1V1	4969	5206	5411
D2V1	4566	4659	4945
D3V1	4001	3596	4201
D1V2	4795	4839	4992
D2V2	4300	4564	4713
D3V2	3652	4004	3878

Conclusion

The highest grain yield (4684.9) kg/ha and highest straw yield (8189.0) kg/ha were obtained by the treatment I3 and the respective lowest grain yield (4380.8) kg/ha and straw yield (7307.8) kg/ha were obtained by the treatment I1. In case of biomass yield I3 obtained the highest value of 12874 kg/ha which was significantly higher than I1 values obtained and highest harvest index (37.4%) was obtained from I1 compared to other irrigation treatments. The highest grain yield (5035.5)kg/ha, straw yield (8401.0)kg/ha and biological yield (13436)kg/ha and harvest index (37.5%) were also recorded in November 30 sowing (D1) and all the lowest values of all these parameters were recorded on December 30 sowing (D3). Wheat variety GW 366, recorded significantly higher grain yield (4613.7) kg/ha than variety MP 1202 (4415.7) kg/ha. Irrigation in crown root initiation + tillering + flowering +milk stage (I3) in combination with November 30 sowing with variety GW-366 (D1I3V1) recorded the highest grain yield (5411) kg/ha. The respective lowest yields 3652 were obtained in the treatment combination of D3I1V2.

Application of research: Study shows yield attributes and yield of wheat were significantly affected with variety, irrigation and sowing time.

Research Category: Irrigation management

Abbreviations: %- Percentage, cm- Centimetre, m- meter, g- Gram, g/cc- Gram/ cubic centimetre, mm- Millimetre, Tmax- Maximum temperature, Tmin- Minimum temperature, °C- Degree Celsius, @- At the rate

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Research project name or number: PhD Thesis

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, J.N.K.V.V, Jabalpur

Cultivar / Variety 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

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