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Irrigation scheduling and soil moisture use on growth and yield of late sown wheat (*Triticum aestivum* L.) varieties

Suraj Gond ✉

Department of Agronomy, GBPUA&T, Pantnagar, Uttarakhand, India

M. K. Singh

Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi, India

S. M. Satapathy

Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi, India

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ABSTRACT

The present investigation was intended to determine the growth , yield capacity and soil moisture use of different late sown varieties of wheat (*Triticum aestivum* L.) under different irrigation schedules. is the present study was undertaken with an objective to evaluate the varietal performance under less moisture availability. To fulfil the aim the field experiment was conducted during winter (*Rabi*) season of 2019-20 with the combination of three irrigation schedules as main plot, and five late sown wheat varieties as sub plot factor, with three replication. Significant impact of three irrigations on crop growth, yield and total soil moisture use was observed over two and one irrigation schedule. Among varieties, WR-544 reported superior growth and yield attributes, where the grain yield was 11.5–15.0% more over MACS-6222, HS-562 and HD-3086, and was at par with HI-1544. Better establishment and tillering capacity of the varieties HI-1544 and WR-544 resulted in efficient moisture utilisation starting from CRI to harvest stage compared to the variety MACS-6222. Irrigation scheduling at the critical moisture stages resulted in efficient soil moisture use by the late-sown varieties HI-1544, WR-544, HS-562 and HD-3086.

Introduction

Wheat (*Triticum aestivum* L.) is the most important crop among all the cereal food grains used for consumption in the world. The production potential of the world was 760.9 million tonnes (M t) from an area of 219.0 million hectares (M ha) and with a productivity of 34.7 q/ha (FAOSTAT, 2020). On the other hand, the wheat area in India was 31.4 M ha, with a production of 107.9 M t and a productivity of 34.4 q/ha (Indiastat, 2020). Green revolution has paved the way for evolution of high yielding wheat varieties which improved the production levels of wheat exponentially. Despite the fact that wheat is second most produced crop besides rice in India, the production is plagued by many factors, of which the most important are inadequate irrigation and poor and imbalanced crop nutrition. Water is essential at every developmental phase starting from seed germination, crop maturity to the harvesting of wheat, and also shares a positive correlation between grain yield and irrigation frequency (Kumar *et al.*, 2015). Efficient water management, being one of the good agronomic management practices, leads to improved crop production and higher yield (Singh *et al.*, 2018). Deficit irrigation considerably reduced agronomic traits as well as grain yield of the wheat cultivars (Moghaddam *et al.*, 2012). Varietal selection is also the most important factor apart from irrigation scheduling to be decided by the farmers before taking up the crop. Improved performance of the newly developed wheat varieties under various management practices can maximize the economic returns under local growing conditions (Sapkota *et al.*, 2007). The shortened growing period adversely affects all growth stages in late sown wheat, such as tillering,

Corresponding author E-mail: *surajshah46039@gmail.com*
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flowering and grain filling. The reduced optimum growth coupled with an increase in temperature leads to leaf senescence and force maturity, resulting in a low photosynthetic rate that is insufficient to satisfy the carbon economy of plants (Sharma *et al.*, 2006). Combination of irrigation scheduling and varietal relation help in selecting best variety under late sown condition of eastern Uttar Pradesh, wherein wheat sowing gets delayed due to late harvest of long duration rice varieties sown in the prior rainy season.

Material and Methods

A field experiment was conducted at the Agricultural Research Farm, BHU, Varanasi, U.P., India during *Rabi* season of 2019-20, under neutral sandy clay loam soil. Total rainfall received during the crop growing period was 32.4 mm. The maximum rainfall (13.0 mm) obtained during the 4th standard week (22-28 of January 2019) and it didn't coincide with irrigation schedules. United States Weather Bureau (USWB) open pan evaporimeter recorded average evaporation (during the crop growing period) wide-ranging from 1.2 to 10.0 mm per day and it was recorded lowest 1.2 mm in 52th week of December 2018. The experiment was laid out in a split plot design having 15 treatment combinations. Three irrigation schedules viz., I_1; one irrigation (CRI stage), I_2; two irrigations (CRI and late jointing stages) and I_3; three irrigations (CRI, late jointing and milking stages) were assigned to main plot and five wheat varieties (viz., MACS-6222, HS-562, HD-3086, WR-544 and HI-1544) were kept in sub plots. The treatments were allocated to main plot and subplot randomly and replicated three times. Soil of the experimental field was low in available N and P, and high in available K. The growth attributes of plant were recorded at 30, 60, 90 DAS and at harvest and yield attributes at harvest. Soil moisture studies were started right from sowing and continued up to maturity of wheat crop. The soil moisture content under all the treatments of three replications was determined before irrigation and 24 hours after irrigation from 0-15, 15-30, 30-60 and 60-90 cm. The soil samples for soil moisture studies were taken with the help of screw auger. The water use efficiency was calculated by using formulae

$$\text{WUE (kg/ha-mm)} = \frac{Y}{CU}$$

Where,

WUE = water use efficiency (kg/ha-mm)
Y = grain yield (kg/ha)
CU = Consumptive use of water (mm)

$$\text{CU} = \frac{M_{1i} - M_{2i}}{100} \times \text{B.Di} \times \text{depth of soil (mm)}$$

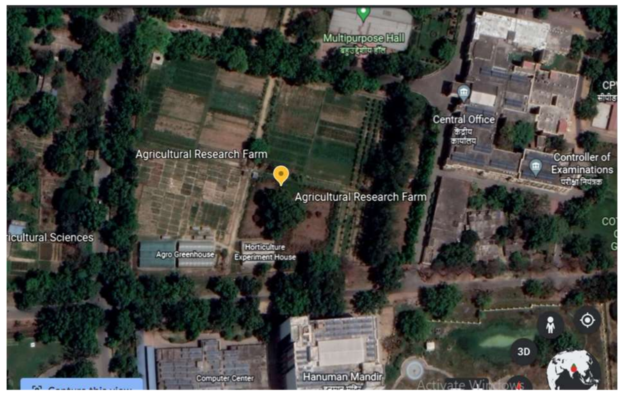

Figure 1: Geotagged image of Agricultural Research Farm IAS, BHU, Varanasi.

Results and Discussion

(A) Growth attributes

The observations showed three irrigations scheduled at CRI, late jointing and milking stages, recorded significantly taller plants (102.01 cm), LAI (4.51) and shoot biomass (605.56 g) over two irrigations (97.64 cm, 4.17 and 555.65g) scheduled at both CRI and late jointing stages and one irrigation scheduled at CRI (88.88 cm, 3.26 and 446.13 g), respectively (table 1). This might be due to more availability of water at three irrigations which enhanced nutrient uptake and metabolic activities translocation and assimilation of plant (Mubeen *et al.,* 2013; Mitra *et al.,* 2015; Kumar *et al.*, 2015).WR-544 was significantly taller than rest of varieties except HI-1544. In terms of LAI, HI-1544 was significantly superior over rest of the varieties except WR-544 and HD-3086 (table 1). WR-544 recorded (563.92g) significantly higher shoot biomass over rest of the varieties except HI-1544 (557.25 g). The differences in plant height, LAI and shoot biomass among various varieties may be due to dry matter accumulation and their genetic constitution. These results are in line with those of (Moghaddam *et al.*, 2012; Abdrabbo *et al.*, 2016).

(B) Yield attributes

(i) Effective tillers and spike length

The higher number of effective tillers (280.43 m^{-2}) and spike length (15.05 cm) were recorded with three irrigations while at par with two irrigations (270.13 m^{-2} and 14.38 cm) and significantly superior over one irrigation (250.33 m^{-2} and 12.22 cm). This might be due to better growth attributes and nutrient uptake consequently less or no tiller mortality with optimum moisture supply when three irrigations were applied (Abdelraouf, *et al.,* 2013; Ali *et al.*, 2014; Kumar *et al.*, 2015). WR-544 recorded effective tillers (277.00 m^{-2}) and spike length (14.78 cm) significantly higher over rest of varieties except with HI-1544 (276.56 m^{-2} and 14.57 cm). Variation in effective tillers and spike

Table 1: Effect of irrigation schedules on growth, yield attributes, straw yield and harvest index of late-sown varieties.

Treatments		Plant height at harvest (cm)	LAI (90DAS)	Shoot biomass at harvest (g m^{-1})	Effective tillers (m^{-2})	Grains spike^{-1}	Spike length (cm)	Test Weight (g)	Straw yield (q/ha)	Harvest index (%)
Irrigation	I_1	88.88	3.26	446.13	259.33	38.10	12.22	34.89	44.60	36.78
	I_2	97.64	4.17	555.65	270.13	42.28	14.38	35.38	48.77	37.86
	I_3	102.01	4.51	605.56	280.43	44.66	15.05	39.60	52.61	39.40
	SEm±	1.03	0.08	8.97	2.98	0.66	0.29	0.88	1.25	0.79
	CD ($P \leq 0.05$)	4.04	0.32	35.21	11.69	2.61	1.13	3.44	4.92	3.15
Varieties	V_1	91.94	3.95	519.45	264.22	40.93	13.04	34.49	47.74	36.72
	V_2	94.14	3.75	520.98	266.56	40.41	13.44	36.75	46.67	37.26
	V_3	99.23	4.20	557.25	276.17	43.17	14.57	38.11	50.96	38.97
	V_4	94.95	3.98	517.30	265.89	40.07	13.58	35.68	46.93	38.10
	V_5	101.07	4.04	563.92	277.00	43.82	14.78	38.08	50.99	39.02
	SEm±	1.63	0.08	10.58	3.28	0.98	0.35	0.84	1.11	0.90
	CD ($P \leq 0.05$)	4.74	0.24	30.88	9.57	2.85	1.03	2.45	3.25	2.66

I_1; one irrigation (CRI stage), I_2; two irrigations (CRI and late jointing stages) and I_3; three irrigations (CRI, late jointing and milking stages). Five wheat varieties V_1: MACS-6222, V_2: HS-562, V_3: HD-3086, V_4: WR-544 and V_5: HI-1544

length were might be due to better growth attributes and genetic potential of the variety (Abdelraouf *et al.,* 2013; Nayak *et al.*, 2015).

(ii) Grains spike^{-1}and 1000 grain weight

The significant highest numbers of grains spike^{-1} and 1000 grain weight were recorded under three irrigation schedules (44.66 and 39.60 g) over two irrigations (42.28 and 35.38 g) and one irrigation (38.10 and 34.89 g), respectively. This might be due to better growth attributes, (like LAI) and nutrient uptake with optimum moisture supply. The lowest number of grains spike^{-1} recorded with one irrigation. It might be due to inadequate moisture at the time of jointing and grain filling stages, caused forced maturity and poor, and shrivelled light weighted grains spike^{-1} (Wang *et al.*, 2016; Abdrabbo *et al.*, 2016). WR-544 (43.83 and 38.08 g) and HD-3086 (40.07 and 38.11 g) were at par with each other and significantly superior over rest of varieties in response of grains spike^{-1}and 1000 grain weight, respectively. It might be due to genetic potential and environmental conditions under late sown condition. Such explanations were also reported by Verma *et al.* (2016); Bachhao *et al.* (2018).

(B) Yield

(i) Grain yield

The significant highest grain yield was recorded with three irrigations (34.20 q/ha) which was 13.19% and 23.95% more over two irrigations and one irrigation, respectively (table 2). The increase in grain yield was to be due to cumulative effect of vegetative growth and yield attributes (Hwary *et al.*, 2011; Abdrabbo *et al.*, 2016; Sharma *et al.*, 2017). WR-544 (32.70 q/ha), recorded significantly higher (15.0, 14.5, and 11.5 %) grain yield over HS-562, MACS-6222, and HD-3086, respectively except HI-1544 (32.43 q/ha). The maximum yield of WR-544 and HI-1544 was attributed due to their higher biomass accumulation, higher number of tillers and better yield attributes. These conclusions were similar to that of Ahmad and Kumar (2015).

Critical assessment of data revealed that interaction effect (I × V) between irrigation schedules and varieties on grain yield was found to be significant and presented in table 2.The grain yield recorded significantly highest in combination of WR-544 (36.93 q/ha) with three irrigations over all other treatment combinations, except combination of HI-1544 (33.88 q/ha) × three irrigations and MACS-6222 × three irrigations. However, treatment combination at two irrigations; HI-1544 (33.88 q/ha) with two irrigations and WR-544 (32.55 q/ha) with two irrigations being at par with each other and found to be significantly higher over rest of treatment combinations. Treatment combination at one irrigation; MACS-6222 × one irrigation recorded significantly lowest grain yield (23.53 q/ha) than HI-1544 × one irrigation, but remained at par with rest of combinations. (Aslam *et al.*, 2014; Abdelkhalek *et al.*, 2015)

Table 2: Interaction effect of irrigation schedules and varieties on grain yield (q/ha)

Treatments (I × V)	I_1	I_2	I_3	**Varietal Mean**
MACS-6222	23.53	25.33	34.95	27.94
HS-562	23.90	26.66	32.83	27.80
HI-1544	30.11	33.30	33.88	32.43
HD-3086	23.89	30.59	32.38	28.95
WR-544	28.63	32.55	36.93	32.70
Irrigation schedule mean	26.01	29.69	34.20	

	SEm±	**CD (*P* ≤0.05)**
Two varieties at the same irrigation schedules	1.17	2.41
Two irrigation schedules at the same or different varieties	1.76	4.06
Irrigation schedules (I)	0.68	2.65
Varieties (V)	0.68	1.97

I_1; one irrigation (CRI stage), I_2; two irrigations (CRI and late jointing stages) and I_3; three irrigations (CRI, late jointing and milking stages).

(ii) Straw yield and harvest index

The maximum straw yield was recorded with the three irrigations (52.61 q/ha) which was significantly superior over two irrigations and one irrigation (table 1). This might be due to combined effect of vegetative growth attributes viz., plant height, shoot dry matter and tillers production. WR-544 (50.99 q/ha) being at par with HI-1544 (50.96 q/ha), and significantly higher than rest of varieties. Varieties WR-544 and HI-1544 were efficient in utilizing biomass towards grain formation as evident from its highest harvest index (39.1%). These findings are in line with those of Tomar *et al.* (2014) and Verma *et al.* (2016). Recorded data clearly indicated that the irrigation schedules had no significant effects on the harvest index. Variety WR-544 (39.02%) being at par with HI-1544 (38.97%), HD-3086 (38.10%), and HS-562 (37.26%) and MACS-6222 (36.72%), respectively (table 1).

(C) Stage wise soil moisture use and water use efficiency

The total soil moisture use due to three irrigations scheduled was found to be significantly higher than two irrigations and one irrigation schedule (table 3). It was due to more demand of water by crop and optimum supply of water through irrigation. Similar results were found by Shivani *et al.* (2003); Mishra and Kushwaha (2016). Stage wise moisture use between CRI - late jointing and milking- harvest by HI-1544 was found significantly higher than MACS-6222 only. However, stage wise moisture use between late jointing - milking stage was found significantly higher in variety WR-544 over rest of varieties. In case of total moisture use, variety WR-544 recorded significantly higher in total moisture use over other varieties except HI-1544.

Table 3: Effect of irrigation schedules on stage wise soil moisture use (mm) and water use efficiency (kg/ha-mm) by wheat varieties

Treatment	Moisture use(mm) and water use efficiency (kg/ha-mm)					
	Sowing to CRI	CRI to late jointing	Late jointing to milking	Milking to harvesting	Total moisture use	WUE
Irrigation schedules (I)						
CRI	44.55	74.38	66.92	42.12	230.98	11.26
CRI and late jointing	44.11	76.81	81.61	62.98	268.51	11.54
CRI, late jointing and milking stage	45.00	81.40	95.87	81.25	306.52	11.62
SEm±	0.42	1.05	1.69	0.97	2.47	0.18
CD ($P \leq 0.05$)	NS	4.11	6.63	3.79	9.69	NS
Varieties (V)						
MACS-6222	44.12	72.09	77.96	56.25	255.22	11.11
HS-562	44.76	77.63	73.94	63.19	264.31	10.97
HI-1544	44.68	80.49	81.91	64.62	276.50	12.06
HD-3086	44.85	79.40	79.27	61.98	270.30	11.19
WR-544	44.35	78.04	85.24	64.57	277.00	12.04
SEm±	0.50	1.34	1.33	1.32	2.17	0.26
CD ($P \leq 0.05$)	NS	3.92	3.88	3.87	6.34	0.76

The maximum WUE was recorded in HI-1544 (12.06 kg/ha-mm) which was at par with WR-544 (12.04 kg/ha-mm) and significant higher over rest of varieties. This might be due to proportionate increase in grain yield per unit consumptive use of water from the soil by the varieties during growing period. (Bikrmaditya *et al.*, 2011; Singh *et al.,* 2012). Regression analysis between grain yield and total soil moisture use resulted in strongly positive correlation. There is an increase of 0.119 q/ha in wheat grain yield per unit total soil moisture utilization at harvesting stage (figure 2).

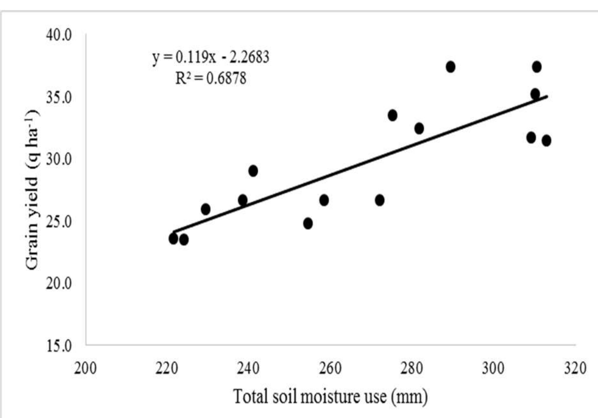

Figure 2: Relationship between total soil moisture use and grain yield of wheat.

Conclusion

Irrigation scheduling resulted in significant variation among the growth parameters as well as yield parameters. Application of three irrigations at CRI stage, late jointing and milking stage resulted in significant increase in growth attributes *viz*. plant height, tillers m^{-1}, LAI and shoot biomass than two irrigations and one irrigation treatments during crop growth period. Also, the yield attributes, yield and total soil moisture use recorded were reportedly had a marked difference with three irrigation schedules. Among the varieties used, WR-544 being at par with HI-1544 recorded higher growth attributes *viz*. plant height, LAI, tillers m^{-1}, 1000 grain weight and shoot biomass. WR-544 being at par with HI-1544 also exhibited significant effect on yield attributes, but also recorded higher grain yield which was followed by "HI-1544". Cultivation of wheat varieties WR-544 and HI-1544 with assured irrigation thrice at CRI stage, late jointing and milking stage can be beneficial with efficient soil moisture use and higher yields under late-sown conditions.

Conflict of interest

The authors declare that they have no conflict of interest.

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