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Studies on irrigation scheduling and nutrient management on wheat growth and productivity

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Abstract

This two-year research was aimed to identify the relationships between irrigation and nutrient management practices on crop growth and yield. Treatments consisted of three irrigation levels viz. recommended critical stages regimes (I_1), irrigation at 0.6 CPE (I_2) and irrigation at 1.0 CPE (I_2) in main plots and four nutrient management practices viz. inorganic nutrient management (F_1), organic nutrient management (F_2), natural farming management (F_3), integrated nutrient management (F_4) in subplots, laid out in split-plot design with three replications. It was revealed that irrigation at 1.0 CPE (I_3) produced significantly taller plants and higher dry matter accumulation but did not influence the days taken for 50 % flowering and physiological maturity. Nutrient management practices also had a significant influence on these parameters in which integrated nutrient management (F_4) was found to be superior for dry matter accumulation, plant height, days taken for 50 % flowering, physiological maturity and yield.

Key words: Irrigation, Nutrient management, Organic, Natural farming, Integrated, Inorganic, wheat

In India, wheat is a major crop and the second most important food crop after rice. It is considered an excellent health-building food containing approximately 78% carbohydrates, 12% protein, 2% fat and minerals, and a considerable amount of vitamins (Kumar *et al*. 2011). About 80 to 85% of wheat grains are ground into flour (atta) and consumed in the form of chapatis, bread, cake, biscuits, pastry and other bakery products. Moreover, wheat straw which is nutritious is mainly used as fodder for livestock. In Himachal Pradesh, about 80 per cent of the total cultivated area in the state is rainfed (HP Economics and Statistics Department, 2021) which faces a lot of environmental constraints. The average productivity of wheat is far behind the attainable productivity of this crop, mainly because of an inadequate and imbalanced supply of irrigation and nutrients. Among the constraints affecting crop production under the rainfed system, water limitation and fertility are the main hindrances. Wheat crop must not be allowed to suffer from water stress at any of the critical stages to obtain maximum yield potential. On the other hand, water should also be utilised efficiently to get higher water productivity. Wheat is highly sensitive to water stress during crown root initiation (CRI) and flowering. However, excess irrigation may lead to heavy vegetative growth and shortening of the reproductive period and ultimately decrease the yield. Although maintaining adequate water throughout the growing season is the most popular way of ensuring higher productivity, but by the imposition of some stress by longer irrigation intervals using CPE ratio or irrigation only at critical stages could also be used not only to attain similar economic yield but saving of irrigation water as well.

Chemical intensive agriculture has brought many degenerative effects on soil health and overall environmental quality since chemical inputs were applied by the farmers beyond the recommended level suggested by the agricultural scientists. The productive capacity of the soil due to deficiency of various nutrients have been widely reported. These

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negative impacts have led to the popularization of organic farming, natural farming and integrated farming which restore and maintain soil health in the long run. A robust complementary relationship exists between the nutrient supply and water availability. Further organic amendments feed the soil microbes, which release the nutrients for the plants. Nowadays, a new concept of natural farming (zero budget) is talked about where the use of organic manures is least and other soil enrichment practices are being advocated. Considering the reasons mentioned earlier, the present investigation was carried out during two consecutive rabi seasons of 2018-19 and 2019-20.

Materials and Methods

A two years field experiment was conducted at the Water Management Farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during *rabi* seasons of 2018-19 and 2019-2020.The experimental site is located at 32° 06′ 05′′ N latitude, 76° 33′ 02′′ E longitude at an elevation of 1283 m above mean sea level. Soil samples were taken from 0-15 cm depth and the physico-chemical properties determined. The soil of the experimental site was silty clay loam in texture, acidic in reaction (pH 5.3) and was rated high in organic carbon and available phosphorus, low in available nitrogen and medium in available potassium. Wheat variety HPW-236 was used in the present investigation.

Irrigation water requirement was calculated based on the daily evaporation data recorded from November to May for 2018-19 and 2019-2020. Irrigation requirement was then calculated by taking into account the difference of actual evaporation and effective rainfall (only positive values) and multiplying with CPE ratios. In the critical stage irrigation regime, irrigation was given at the CRI stage, tillering, late jointing, flowering and dough stage. The total effective rainfall was 372 mm in 2018 and 470 mm in 2019. The total amount of irrigation water applied for the critical stage (**I_1**) was 250 mm in both the years, 156 and mm 76 for (**I_2**) in 2018 and 2019 respectively and 260 mm and 126 mm for (**I_3**) in 2018 and 2019, respectively.

Four nutrient management practices were adopted *viz*. inorganic nutrient management (**F_1**) where chemical fertilizers were applied at the recommended dose of 120:60:30 N:P:K kg ha^{-1}. In organic nutrient management (**F_2**), the seeds treated with azotobacter and PSB were sown in the field which was provided with 15 tonnes FYM ha^{-1} while vermiwash was applied through foliar route at 30 days interval. In natural farming management (F_3), powdered *ghanjeevamrit* was applied and incorporated in the soil @395 kg ha^{-1}. Seeds were treated with *bijamrit* and dried under the shade for 30 minutes before sowing. Foliar application with *jeevamrit* was made at 30 days intervals. Mulch was applied in the inter-rows of crops for moisture conservation. In integrated nutrient management (**F_4**), 75 % of the nutrient requirement was applied through Urea, SSP and MOP and the remaining through FYM, Azotobacter and PSB as a seed treatment. The nutrient content in terms of N:P:K was 2.26: 0.12: 0.46 in *bijamrit, jeevamrit*: 1.93: 0.16: 2.6 and *ghanjeevamrit*: 1.33: 0.84: 0.73. FYM contained 0.47 % N, 0.37 % P and 0.62 % K on 70% moisture basis.The produce from each net plot was harvested and threshed after sun drying. The grains were cleaned and weighed after threshing. The weight of grains per net plot was converted into quintals per hectare (q/ha). Detailed treatment is given in table 1.

Table 1. Detailed treatment of the study

Main plot: Irrigation schedules
I_1: Recommended critical stages
I_2: Irrigation at 0.6 CPE
I_3: Irrigation at 1.0 CPE
Sub plot: Nutrient Management Practice
F_1: Inorganic management (120:60:30 N:P_2O_5:K_2O kg ha^{-1})
F_2: Organic management (15 t FYM +Azotobacter + PSB (seed treatment) +Vermiwash (monthly interval)
F_3: Natural farming management (Mulch+ Bijamrit + Jeevamrit + Ghanjeevamrit as per recommendations)
F_4: Integrated management (75% NPK+ 25% N through FYM + Azospirillium/Azotobacter + PSB (seed treatment)

Result and Discussion

Growth studies

Irrigation scheduling significantly influenced the plant height in both years of the study in which taller plants were recorded when irrigation was given at 1.0 CPE (**I_3**) followed by irrigation at 0.6 CPE (**I_2**) which was although at par with recommended critical stages regime (**I_1**) throughout the growing (Table 2). Water, being a component of photosynthesis, plays one of the most important roles in cell enlargement due to turgor pressure and cell division resulting in the rapid growth of the plant cells which ultimately increase the plant height and overall growth of the plant. Adequate water

Integrated | Natural | Organic | Inorganic

Table 2. Effect of irrigation scheduling and nutrient management on plant height at different interval of wheat

Treatments	Plant height (cm)							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2018	2019	2018	2019	2018	2019	2018	2019
Main plot: Irrigation schedules								
I_1	15.90	16.04	18.09	19.78	35.56	36.05	78.19	79.36
I_2	16.76	16.71	19.60	21.22	38.18	38.76	80.39	82.26
I_3	17.92	18.33	21.72	24.00	41.96	42.12	85.50	88.03
CD (P=0.05)	1.23	1.42	1.62	2.36	2.94	2.78	4.28	4.21
Sub plot: Nutrient Management Practice								
F_1	19.10	18.64	22.39	23.88	42.37	41.75	88.71	87.88
F_2	15.71	16.10	18.31	20.35	35.13	36.05	74.49	76.92
F_3	13.27	13.60	15.46	17.06	30.46	31.28	65.23	68.81
F_4	19.36	19.76	23.06	25.37	46.29	46.82a	97.01	99.27
CD (P=0.05)	2.25	2.22	2.44	1.94	3.38	3.84	5.72	6.78

I_1 :Recommended critical stages, **I_2** : Irrigation at 0.6 CPE, **I_3** : Irrigation at 1.0 CPE
F_1 : Inorganic management (120:60:30 N:P_2O_5:K_2O kg ha^{-1}), **F_2** : Organic management (15 t FYM + Azospirillium/Azotobacter + PSB (seed treatment) + Vermiwash (monthly interval), **F_3** : Natural farming management (Bijamrit + Jeevamrit + Ghanjeevamrit as per recommendations), **F_4** : Integrated management (75% NPK+ 25% N through FYM + Azospirillium/Azotobacter + PSB (seed treatment)

in the rhizosphere through frequent irrigation in 1.0 CPE (**I**$_3$) might have led to the solubilisation of plant nutrients in the soil and made them available to the roots, enhancing the nutrient uptake resulting in robust vegetative growth. Kumar *et al*. (2016) and Kumar *et al*. (2021) also reported taller plants with higher irrigation levels.In case of dry matter accumulation at 60 and 90 DAS, significantly higher dry matter accumulation was recorded when irrigation was given at 1.0 CPE (**I**$_3$) followed by irrigation at 0.6 CPE (**I**$_2$) and recommended critical stages regimes (**I**$_1$), in that order, each treatment differing significantly to one another. The higher dry matter accumulation in (**I**$_3$) and (**I**$_2$) might be due to frequent intervals of irrigation which results in maintaining adequate moisture ~~maintenance~~ in the rhizosphere leading to better root growth, mobilizing nutrients and maintaining higher photosynthetic rate by virtue of turgid stomatal conductance. These results also conform to Vishuddha *et al*. (2014), Nand *et al*. (2014) and Kumar *et al*. (2021), who reported higher dry matter accumulation with higher irrigation levels.

Nutrient management also played an important role in the plant height and dry matter accumulation. Among the different nutrient management practices, integrated nutrient management (**F**$_4$), remaining statistically at par with inorganicnutrient management (**F**$_1$) recorded significantly taller plants and higher dry matter accumulation compared to organic nutrient management (**F**$_2$) and Natural farming management (**F**$_3$) up to 60 (Tables 2 and 3) However, from 90 DAS up to 120 DAS, significantly taller plants as well as

Inorganic | Organic | Natural | Integrated

Table 3. Effect of irrigation scheduling and nutrient management on dry matter accumulation of wheat

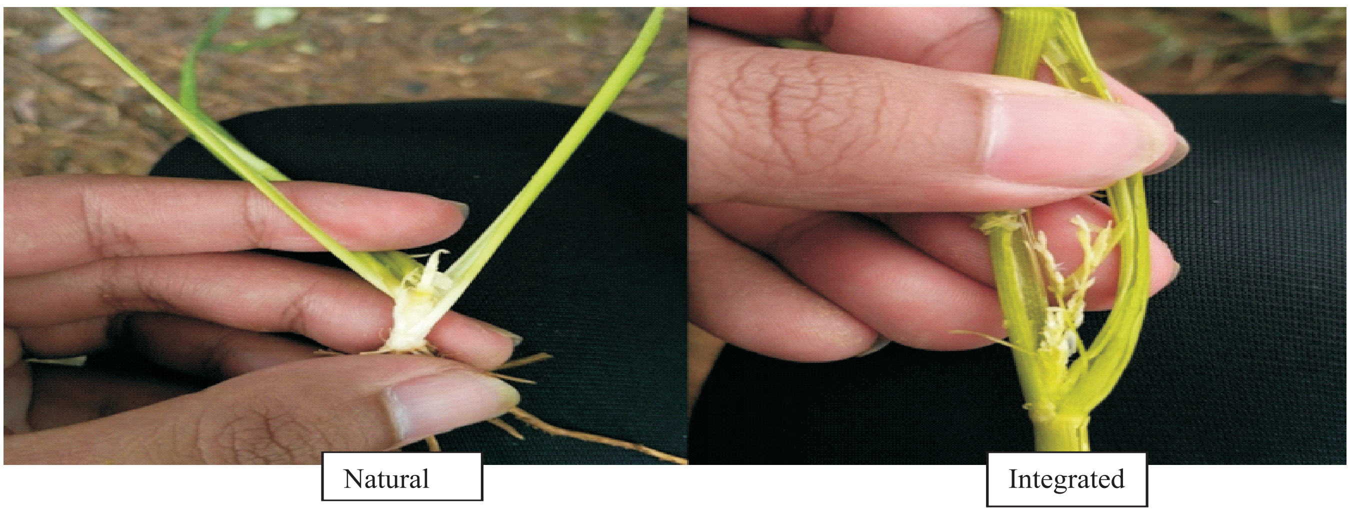
Treatments	Dry matter accumulation (g m^{-2})							
	30 DAS		60 DAS		90 DAS		120 DAS	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Main plot: Irrigation schedules								
I$_1$	20.67	22.00	39.21	42.28	74.50	75.17	263.06	265.42
I$_2$	21.56	23.13	43.13	45.09	81.48	85.27	267.50	277.37
I$_3$	23.20	24.88	48.11	51.36	87.82	92.65	290.46	305.49
CD (P=0.05)	1.79	2.02	3.90	2.76	6.31	5.94	20.15	24.98
Sub plot: Nutrient Management Practice								
F$_1$	24.82	25.77	49.04	51.13	89.40	90.27	297.81	304.54
F$_2$	19.86	21.47	40.12	43.95	74.00	78.13	251.42	262.78
F$_3$	17.39	18.81	34.11	36.33	64.1d	67.77	219.81	227.99
F$_4$	25.17	27.31	50.66	53.57	97.51	101.28	325.66	335.73
CD (P=0.05)	2.70	2.61	5.51	5.33	7.17	8.34	23.72	25.20

I$_1$:Recommended critical stages, I$_2$: Irrigation at 0.6 CPE, I$_3$: Irrigation at 1.0 CPE

F$_1$: Inorganic management (120:60:30 N:P_2O_5:K_2O kg ha^{-1}),**F$_2$**: Organic management (15 t FYM + Azospirillium/Azotobacter + PSB (seed treatment) + Vermiwash (monthly interval), **F$_3$**: Natural farming management (*Bijamrit* + *Jeevamrit* + *Ghanjeevamrit* as per recommendations), **F$_4$**: Integrated management (75% NPK+ 25% N through FYM + Azospirillium/Azotobacter + PSB (seed treatment) higher dry matter accumulation were observed in integrated nutrient management ($\mathbf{F_4}$) followed by inorganic nutrient management ($\mathbf{F_1}$), organic nutrient management ($\mathbf{F_2}$)and natural farming management ($\mathbf{F_3}$), all the treatments differing significantly from each other. The taller plants in integrated nutrient management ($\mathbf{F_4}$) might be due to the immediate release of plant nutrients from inorganic sources as well as the cumulative build-up of plant nutrients released from FYM applied in the preceding season. The application of PSB and azotobacter along with FYM have contributed to the mobilization and mineralization of plant nutrients Sain and Chaplot (2014) in the rhizosphere which was taken up by the plants easily. The benefits of integrating organic and inorganic nutrient sources were also reported by Neelam *et al*. (2014) and Fazily *et al*. (2021). Since dry matter accumulation is directly proportional to the vegetative growth of the plant, the lower dry matter accumulation in organic nutrient management ($\mathbf{F_2}$) and natural farming management ($\mathbf{F_3}$) may be due to the nutrient sources which did not fulfill the nutrient requirement of the crop resulting in low vegetative growth as compared to integrated nutrient management ($\mathbf{F_4}$) and inorganic nutrient management ($\mathbf{F_1}$). These results agree with that of Singh *et al.* (2013). Sain and Chaplot (2014) who reported that seed inoculation with azotobacter proved effective as it significantly improved plant height and dry matter accumulation of wheat over no inoculation. Inadequate plant nutrients might have been the main cause of lower growth in organic and natural farming management systems than inorganic and integrated management systems.

Developmental studies

The number of days taken to 50 % flowering and physiological maturity not differ significantly with different irrigation schedules whereas these parameters were significantly affected by nutrient management practices (Table 4). In both the years,



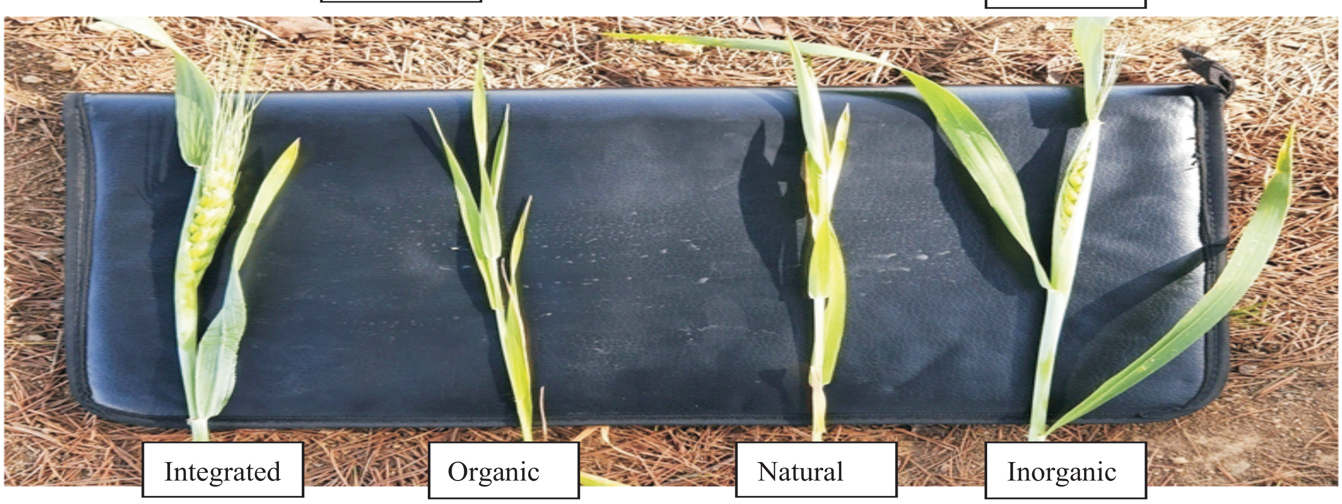


Table 4. Effect of irrigation scheduling and nutrient management on days to 50 % flowering and physiological maturity of wheat

Treatments	Days to 50 % flowering		Days to physiological maturity		Grain Yield(q ha^{-1})	
	2018	2019	2018	2019	2018	2019
Main plot: Irrigation schedules						
I_1	132.3	136.5	167.4	175.7	24.7	25.6
I_2	129.4	132.9	164.3	171.3	25.6	26.3
I_3	128.4	131.9	163.1	169.2	26.8	27.9
CD (P=0.05)	NS	NS	NS	NS	1.17	1.36
Sub plot: Nutrient Management Practice						
F_1	127.1	131.0	161.0	168.6	31.15	30.27
F_2	133.5	137.0	169.1	176.2	19.61	20.78
F_3	134.4	138.2	170.5	177.7	19.05	19.51
F_4	125.3	128.9	159.1	165.7	33.10	36.09
CD (P=0.05)	4.9	5.2	5.8	6.5	0.87	0.92

I_1:Recommended critical stages, **I_2**: Irrigation at 0.6 CPE, **I_3**: Irrigation at 1.0 CPE

F_1: Inorganic management (120:60:30 N:P_2O_5:K_2O kg ha^{-1}),F_2: Organic management (15 t FYM + Azospirillium/Azotobacter + PSB (seed treatment) + Vermiwash (monthly interval), **F_3**: Natural farming management (*Bijamrit* + *Jeevamrit* + *Ghanjeevamrit* as per recommendations), **F_4**: Integrated management (75% NPK+ 25% N through FYM + Azospirillium/Azotobacter + PSB (seed treatment)

integrated nutrient management (F_4) being statistically at par with inorganic nutrient management (F_1) took significantly lower number of days for 50 % flowering as well as physiological maturity as compared to organic nutrient management (F_2) and natural farming management (F_3). Moreover, the latter two treatments were also at par with each other. Due to inadequate and low nutrient supply in organic and natural treatments, the plant's growth and development were affected, thereby affecting the phenological stages. This could be due to the application of an organic source of nutrients that might have prolonged the vegetative phases of crop growth (Krishna *et al*. 2008) resulting in more number days taken for flowering and maturity.

Yield

Significantly higher grain yield was recorded when irrigation was given at irrigation at 1.0 CPE (I_3). However, irrigation at 0.6 CPE (I_2) and recommended critical stages regimes (I_1) were at par with one another (Table 4). Frequent and adequate moisture supply through irrigation in CPE must have enhanced the root system thereby enhancing the scavenging areas for available nutrient in the soil for uptake by the plants during the whole crop season. The result corroborates with the findings of Bikrmaditya *et al*. (2011), Nayak *et al*. (2015) Mishra and Kushwaha (2016) and Verma *et al*. (2017) who also reported a significant influence on grain yield when irrigations were applied judiciously comparison with higher irrigation levels.

Among the different nutrient management practices, significantly higher grain yield was recorded in integrated nutrient management (F_4) followed by inorganic nutrient management (F_1),Organic nutrient management (F_2) and Natural farming management (F_3). Higher yield in integrated nutrient management (F_4) might be due to the use of FYM and inorganic fertilizer in conjunction as well as application of biofertilisers which increased the availability of NPK, improvement of soil physical condition and biological activity of soil resulted in higher yield. However, in organic nutrient management (F_2) and natural farming management system (F_3) where nutrient requirements were partially available through *jeevamrit* and *ghanjeevamrit,* low nutrient content could not supply nutrients in adequate amounts for the optimum grain yield. The use of organic manure alone in organic nutrient management ($\mathbf{F}_2$) and natural farming management system ($\mathbf{F}_3$) resulted inlower yield which shows that organic manure alone cannot satisfy the nutrients demands of wheat (Sheoran *et al*. 2017) as sink capacity of a plant depends mainly on vegetative growth that is positively affected by application of nitrogen fertilizers and supply of photosynthesis for the formation of yield components. Kler *et al*. (2017), Sharma *et al*. (2015), Mohan *et al*. (2018) and Maurya et al. (2019) also concluded that significantly higher and grain yield of wheat by application of inorganic and organic sources of nutrients were due to balanced proportions of plant nutrients during the whole crop season that increased the yield attributing characters and yield of wheat.

Conclusion: Based on two years investigation, it can be concluded that irrigation at 1.0 CPE (I_3) recorded higher growth of wheat as well as higher yield as compared to irrigation at 0.6 CPE ($\mathbf{I}_2$) and recommended critical stages regimes ($\mathbf{I}_1$). However, it did not influence days taken for 50 % flowering and physiological maturity. Among the different nutrient management practices, integrated nutrient management ($\mathbf{F}_4$) was found to be superior for dry matter accumulation, plant height, days taken for 50 % flowering, physiological maturity and yield of wheat.

Conflicts of interest: There is no conflict of interest in this research paper.

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