Studies on irrigation scheduling, moisture conservation practices and nutrient management on performance of wheat (*Triticum aestivum* L.)

Abstract

A field experiment was conducted during two consecutive *Rabi* seasons 2020-21 and 2021-22 at Students' Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India**.** The field experiment allocated three irrigation scheduling namely: I_1: two irrigations at CRI (crown root initiation) and Jointing stage, I_2: three irrigations at CRI, Jointing and Booting stage and I_3: Four irrigations at CRI, Tillering, Booting and Milking stage, two moisture conservation practices *viz:* M_0: without mulching and M_1: Organic mulch at the rate of 10 t ha^{-1} + Kaolin 6% spray and three nutrient management practices *viz:* N_1: 100% Recommended dose of fertilizers (RDF) (150:60:40 kg ha^{-1} NPK), N_2: 85% RDF + Farm yard manure (FYM) @ 5.0 t ha^{-1} and N_3: 75% RDF + FYM @ 10.0 t ha^{-1}. The field experiment was laid out in double split plot design with three replications. On pooled basis of two years experimentation the results indicated that, four irrigations at CRI, Tillering, Booting and Milking stage recorded significantly highest value of crop growth rate (CGR) (13.15 and 19.28 g m^{-2} day^{-1} at 30-60 and 60-90 days after sowing (DAS), respectively), grain yield (4381.60 kg ha^{-1}) and consumptive use of water (457.39 mm) while, significantly highest water use efficiency (11.97 kg ha^{-1} mm) was received under two irrigations at CRI and Jointing stage over the rest of irrigation schedules. In respect of moisture conservation practices, organic mulch @ 10 t ha^{-1} + Kaolin 6% spray recorded significantly water use efficiency (11.41 kg ha^{-1} mm) compared to without mulching treatment while, highest consumptive use of water (380.72 mm) was recorded under without mulching. Integration of 85% RDF + FYM @ 5.0 t ha^{-1} recorded significantly maximum water use efficiency (10.99 kg ha^{-1} mm) compared to other treatments while, highest consumptive use of water (381.41 mm) was recorded under the treatment of 100% RDF.

Key words: Consumptive use of water, Kaolin, Moisture conservation practices, Nutrient management, Organic mulch, Water use efficiency

Introduction:

"Wheat (*Triticum aestivum* L.) is one of the most important staple food crops of the world as well as India. It is cultivated under diverse growing conditions of soil and climate. In India, it is the second most important food crop after rice" **Kumar *et al*.,(2021)**. Wheat is highly sensitive to water stress during CRI and flowering, but excessive irrigation may result in heavy vegetative growth, a shorter reproductive period, and a lower yield. However, maintaining a high water status throughout the growing season is required to ensure uninterrupted crop growth and high economic yield. Proper irrigation scheduling is required during both the vegetative and reproductive phases to maintain the optimum moisture regime for excellent crop growth and development in a changing climatic scenario with abrupt temperature changes. Moisture conservation with organic mulch helps to mitigate the drought stress, increase water productivity and reduce the soil degradation, resulting in enhancing the productivity of crops. Mulches are known to buffer soil temperature because it prevents soil water loss by evaporation. The Indian agriculture with its two prominent cropping seasons [summer (Kharif) and winter (Rabi)] is the mainstay of the rural economy. Northwest India (NWI) is an important region for the cultivation of Rabi crops grown during the period from October to April[Nageswararao et al. 2018]. **Zhang et al., (2003)** reported that "straw mulching in winter wheat reduced soil evaporation by 40 mm and improved water use efficiency over 10 per cent". "The spray of kaolin on wheat crop resulted in better growth parameters. They attributed the favourable effect of kaolin spray on plant growth which might be due to reduction in transpirational losses of water due to reflection of part of solar radiation incident on leaf surface, thus making the soil moisture available for better growth over longer period" **Thakuria *et al.*, (2004).** Increased fertilizer levels can increase production, but continuous use of chemical fertilizers alone may result in diminishable yield even with the recommended dose of fertilizer application. Furthermore, chemical fertilizer alone may have the same significant effect on the physical and chemical properties of soil and may not be as profitable unless soil fertility is maintained at a sustainable level through the application of organic manures. Organic manures, such as farmyard manure, should be considered an integral component and may aid in the recovery of soil health in cropping systems by improving soil fertility and physical properties. In this context, FYM are of paramount importance for application in food crops and helps in maintaining soil fertility and productivity.

Material and Methods:

A field experiment was conducted during two consecutive *Rabi* seasons 2020-21 and 2021-22 at Students' Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India, situated at 125.9 meter altitude, 26.49122^0 North latitude, 80.307012^0 East longitude**.** The experiment consisted three irrigation scheduling *viz:* I_1: two irrigations at CRI and Jointing stage, I_2: three irrigations at CRI, Jointing and Booting stage and I_3: four irrigations at CRI, Tillering, Booting and Milking stage, two moisture conservation practices *viz:* M_0: without mulching and M_1: organic mulch @ 10 t ha^{-1} + Kaolin 6% spray and three nutrient management treatments *viz:* N_1: 100% RDF (150:60:40 kg ha^{-1} NPK), N_2: 85% RDF + FYM @ 5.0 t ha^{-1} and N_3: 75% RDF + FYM @ 10.0 t ha^{-1}. The field experiment was framed in double split plot design with three replications. The variety, *HD-2967* was used for sowing in experiment. The soil of experimental field was moist, well drained with uniform plane topography. The soil of the experimental field was alluvial in origin, sandy loam in texture and slightly alkaline in reaction having pH 7.69 and 7.67 (1:2.5 soil: water suspension method given by **Jackson, 1973**), low organic carbon (0.30 % and 0.29 % Walkley and Black's rapid titration method given by **Walkley and Black, 1934**), with medium available nitrogen 181.40 and 179.25 kg ha^{-1} (Alkaline permanganate method given by **Subbiah and Asija, 1956**), low in available phosphorus as sodium bicarbonate-extractable P was 12.50 and 11.28 kg ha^{-1} (Olsen's calorimetrically method**, Olsen *et al.*, 1954**) and medium in available potassium was 170.0 and 168.25 kg ha^{-1} (Flame photometer method given by **Hanwey and Heidel, 1952**) respectively, in 2020-21 and 2021-22. Mulching was undertaken in respective treatment with paddy straw @ 10 t ha^{-1}. Respective treatments were treated with two spray of kaolin @ 6% solution on 49 DAS (at maximum Tillering stage) and 69 DAS (20 days, after first spray). The experimental soil was fertilized as per treatments. The crop received bright sunshine in terms of daily minimum temperature and maximum temperature during the study period varied between 6.0^0C to 21.3^0C and 4.9^0C to 21.1^0C and 17.0^0C to 39.6^0C and 15.7^0C to 40.9^0C during 2020-21 and 2021-22, respectively. During the crop period, a total rainfall of 16.5 mm was received in 2020-21 and 63.9 mm in 2021-22. Over all the climatic condition during study of both year was found favourable for crop proper growth and development except maximum temperature at dough stage during 2021-22 creates hot climatic condition which causes slight shrinkage of grain results in weight of grain ear^{-1} and test weight decreases and ultimately reduce the grain yield upto 8.6% in comparison to 2020-21.

Results and Discussion:

Growth:

Irrigation scheduling significantly influenced growth parameters in terms of plant height and crop growth rate at 30-60 and 60-90 DAS **Jana *et al.* (2001)** and it were recorded maximum under four irrigations at CRI, Tillering, Booting and Milking stage compared to rest of irrigation treatments (Table 1). Elongation in plant height may be attributed due to provided adequate supply of irrigation water at each critical growth stage of crop which induced rapid cell division and cell elongation and higher crop growth rate was attributed to increased plant height and more dry matter accumulation in vegetative parts of plant due to adequate available soil moisture and favourable soil temperature. Use of organic mulch @ 10 t ha^{-1} + Kaolin 6% spray significantly increased plant height and crop growth rate at 30-60 and 60-90 DAS in comparison to without mulching. It was might be due to organic mulching increased better availability of conserved soil moisture in root zone by reducing evaporation losses of water from soil (**Sarwar *et al.*, 2013)** and kaolin spray also reduced transpiration losses of water from leaf surface of plant **Tfwala *et al.* (2021)** by reflecting solar radiation results in more assimilation of photosynthates in reproductive parts of plant. Integration of 85% RDF + FYM @ 5.0 t ha^{-1} recorded maximum plant height and higher crop growth rate at 30-60 and 60-90 DAS over the rest of treatments (Table 1). "Higher crop growth rate was maintained due to high leaf area index which resulted in higher dry matter accumulation at a faster rate per unit leaf area per unit time by reducing mortality of tillers and senescence of leaves" **Thakur *et al.* (2021)** and **Choudhary *et al.* (2022).** It has been visualized that protein synthesis and protoplasm increased cell size and finally responsible for greater vertical development of plant **(Singh and Agarwal, 2001)**.

Water use efficiency:

Significantly maximum water use efficiency was received under two irrigations at CRI and Jointing stage and decreased as such as number of irrigation increases and it was higher 24.94% compared to four irrigations at CRI, Tillering, Booting and Milking stage (Table 2).This mean that production of grain per mm of water used decreased with the increase the number of irrigations and the relative increase in the grain yield of wheat has not been in proportion to the increase in consumptive use of water, thereby resulting in decrease the water use efficiency under four irrigations at CRI, Tillering, Booting and Milking stage. **Dutta and Mondal (2006)** also concluded that, increase in number of irrigation leading to increase in consumptive use of water and decrease in water use efficiency. Similar findings of present investigation were also reported by **Ahmad (2002)**, **Kibe and Singh (2003)** and **Gupta *et al.*, (2016).** The treatment receiving organic mulch @ 10 t ha^{-1} + Kaolin 6% spray exhibited significant result on water use efficiency and it increased by 14.10% compared to without mulching treatment (Table 2). It may be due to production of grain per mm water used increased with mulching and kaolin spray because it increases moisture retention capacity of soil by reducing evapotranspiration losses of water **Tfwala *et al.* (2021)** and **Qin *et al.*, (2015).** Integration of 85% RDF + FYM @ 5.0 t ha^{-1} was found significantly superior for increasing upto 5.47% water use efficiency over to 75% RDF + FYM @ 10.0 t ha^{-1} (Table 2). The increase in water use efficiency might be due to integration of FYM with RDF of fertilizer exhibited to their favourable effect on growth parameters which are influenced yield attributes and ultimately grain yield of crop. Similar findings were also reported by **Sarma *et al.*, (2005).**

Consumptive use of water:

Consumptive use of water was closely related to the amount of water applied through irrigation and also varied with number of irrigations. It was markedly higher (52.78%) under four irrigations at CRI, Tillering, Booting and Milking stage as compared to treatment received two irrigations at CRI, and Booting stage which received lowest consumptive use of water (Table 2). This might be due to the fact that under more frequent wetting cycles, evaporation was at potential rate due to availability of high soil moisture than the crop irrigated at wider intervals as was the case with limited irrigation condition and more frequent irrigations resulting in more moisture available to the crop and soil surface and increased evapotranspiration. Similar findings of present investigation were also reported by **Ahmad (2002)**, **Kibe and Singh (2003)** and **Gupta *et al.*, (2016).** Consumptive use of water by wheat was recorded to be markedly higher with no mulching treatment as compared to treatment received organic mulch @ 10 t ha^{-1} with kaolin 6% spray (Table 2). This was might be due to effect of mulching, play an important role in the conservation of soil moisture by reducing evaporation losses of water from soil and kaolin also reduced transpiration losses of water from aerial parts of plant mainly from surface of leaves by reflecting solar radiation results in decreased consumptive use of water by wheat **Tfwala *et al.* (2021)** and **Qin *et al.,* (2015).** It was observed that only 18% of water loss occurred due to evaporation from soil. While, transpirational loss accounted for as much as 64% in the arid zones. Therefore the possibility of reducing transpirational loss of water with anti-transpirants (kaolin) without reducing photosynthesis is of immense practical importance. Application of 100% RDF recorded the highest consumptive use of water and it was higher (1.80%) compared to 75% RDF + FYM @ 10 t ha^{-1} (Table 2). Similar findings were also reported by **Sarma *et al.,* (2005).**

Yield:

Significantly highest yield was recorded with four irrigations at CRI, Tillering, Booting and Milking stage and it was significantly superior by 22.30% in grain yield, 14.74% in straw yield and 3.98% in harvest index over to treatment received two irrigations at CRI, and Booting stage (Table 3). The increase in yield of wheat in present investigation might be due to increase in yield attributing characters with adequate availability of moisture gained through application of more number of irrigations. Beneficial effect of application of higher irrigation levels on wheat yield is well documented by **Thakur *et al.* (2000), Jana *et al.* (2001)**, **Meena *et al.,* (2015**) and **Niwas *et al.,* (2019)**. Similarly significant improvement in yield owing to application of organic mulch @ 10 t ha^{-1} + Kaolin 6% spray could be ascribed to its favourable effect on plant growth and yield attributes and it was significantly superior to without mulching by reported an increment of 12.76% in grain yield, and 11.60% in straw yield. However, difference was found non-significant in harvest index (Table 3). Results of similar nature have already been observed by **Lakra *et al.,* (2022)** and **Nateghi *et al.,* (2013).** Integration of 85% RDF + FYM @ 5.0 t ha^{-1} recorded highest grain and straw yield and it was significantly higher 7.16% and 4.37%, respectively in comparison to 75% RDF + FYM @ 10.0 t ha^{-1} and do not produces significant response in harvest index (Table 3). The results of present investigation are corroborated with the findings of **Gangmei *et al.,* (2022)**, **Akhtar *et al.,* (2018), Singh *et al.* (2021)**, and **Choudhary *et al.* (2022).** The reason for such increase in yield of wheat may be due to the fact that integration of FYM with fertilizer doses, which supplied available plant nutrients directly to plants and created congenial soil environment results in increased nutrient use efficiency and water holding capacity of soil for a longer time, which resulted better growth in terms of yield parameters and ultimately increases grain and straw yield of wheat.

Conclusion:

On the basis of above findings of result, it is concluded that, four irrigations at CRI, Tillering, Booting and Milking stage, organic mulch @ 10 t ha^{-1} + Kaolin 6% spray and 85% RDF (150 kg N, 60 kg P_2O_5 & 40 kg K_2O ha^{-1}) + FYM @ 5.0 t ha^{-1} were found significantly superior for increasing plant growth, consumptive use of water and yield of wheat. While, water use efficiency was found significantly higher when applied least number of irrigations (two irrigations at CRI and Jointing stage, organic mulch @ 10 t ha^{-1} + Kaolin 6% spray and 85% RDF (150 kg N, 60 kg P_2O_5 & 40 kg K_2O ha^{-1}) + FYM @ 5.0 t ha^{-1}.

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Treatments	Plant height (cm) at harvest			CGR (Sowing – 30 DAS) g m^{-2} day^{-1}			CGR (30 – 60 DAS) g m^{-2} day^{-1}			CGR (60– 90 DAS) g m^{-2} day^{-1}		
	2020-21	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
A. Irrigation scheduling												
Two irrigations at CRI and Jointing stage	78.65	80.16	79.40	0.499	0.502	0.500	7.76	7.98	7.87	17.63	17.68	17.65
Three irrigations at CRI, Jointing and Booting stage	82.46	84.00	83.23	0.500	0.503	0.501	11.14	11.40	11.27	18.55	18.56	18.56
Four irrigations at CRI, Tillering, Booting and Milking stage	89.26	90.61	89.94	0.502	0.505	0.503	12.99	13.30	13.15	19.27	19.29	19.28
SEd±	**1.23**	**1.39**	**0.93**	**0.024**	**0.026**	**0.017**	**0.21**	**0.24**	**0.16**	**0.15**	**0.16**	**0.11**
CD at 5%	**3.43**	**3.86**	**2.14**	**NS**	**NS**	**NS**	**0.58**	**0.67**	**0.37**	**0.42**	**0.44**	**0.25**
B. Moisture conservation practices												
Without mulching	82.14	83.60	82.87	0.499	0.502	0.501	10.41	10.68	10.54	18.36	18.40	18.38
Organic mulch @ 10 t ha-1 + Kaolin 6% spray	84.77	86.25	85.51	0.501	0.504	0.503	10.85	11.11	10.98	18.60	18.62	18.61
SEd±	**1.02**	**1.05**	**0.73**	**0.017**	**0.019**	**0.013**	**0.17**	**0.17**	**0.12**	**0.10**	**0.08**	**0.06**
CD at 5%	**2.50**	**2.58**	**1.60**	**NS**	**NS**	**NS**	**0.42**	**0.42**	**0.26**	**0.24**	**0.21**	**0.14**
C. Nutrient management												
100% RDF (150:60:40 kg ha^{-1} NPK)	83.20	84.33	83.76	0.499	0.502	0.500	10.56	10.82	10.69	18.52	18.56	18.54
85% RDF + FYM @ 5 t ha^{-1}	85.86	88.00	86.93	0.502	0.505	0.503	10.90	11.20	11.05	18.79	18.80	18.80
75% RDF + FYM @ 10 t ha^{-1}	81.31	82.45	81.88	0.500	0.503	0.501	10.42	10.67	10.55	18.14	18.16	18.15
SEd±	**1.30**	**1.33**	**0.93**	**0.024**	**0.026**	**0.018**	**0.17**	**0.18**	**0.12**	**0.17**	**0.19**	**0.13**
CD at 5%	**2.69**	**2.75**	**1.87**	**NS**	**NS**	**NS**	**0.35**	**0.38**	**0.25**	**0.36**	**0.39**	**0.26**
D. Interactions (A×B×C)												

SEd±	**3.20**	**3.26**	**2.28**	**0.058**	**0.063**	**0.045**	**0.42**	**0.45**	**0.31**	**0.43**	**0.47**	**0.32**
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table: 1 Effect of treatments on growth of wheat

Table: 2 Effect of treatments on water use efficiency and consumptive use of water of wheat

Treatments	**Water use efficiency (kg ha^{-1} mm)**			**Consumptive use of water (mm)**		
	2020-21	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
A. Irrigation scheduling						
Two irrigations at CRI and Jointing stage	12.56	11.39	11.97	297.21	302.70	299.36
Three irrigations at CRI, Jointing and Booting stage	11.07	10.05	10.56	377.30	383.82	379.76
Four irrigations at CRI, Tillering, Booting and Milking stage	10.03	9.13	9.58	455.03	462.90	457.39
SEd±	**0.26**	**0.20**	**0.08**	**3.42**	**4.44**	**2.80**
CD at 5%	**0.74**	**0.57**	**0.19**	**9.51**	**12.34**	**6.47**
B. Moisture conservation practices						
Without mulching	10.48	9.52	10.00	378.27	385.04	380.72
Organic mulch @ 10 t ha^{-1} + Kaolin 6% spray	11.95	10.86	11.41	374.75	381.23	376.95
SEd±	**0.21**	**0.17**	**0.05**	**3.74**	**5.12**	**3.17**
CD at 5%	**0.52**	**0.41**	**0.12**	**NS**	**NS**	**NS**
C. Nutrient management						
100% RDF (150:60:40 kg ha^{-1} NPK)	11.21	10.17	10.69	378.95	385.50	381.41
85% RDF + FYM @ 5 t ha^{-1}	11.51	10.47	10.99	378.40	385.28	380.44
75% RDF + FYM @ 10 t ha^{-1}	10.93	9.92	10.42	372.20	378.63	374.66
SEd±	**0.30**	**0.24**	**0.04**	**4.58**	**6.27**	**3.88**
CD at 5%	**NS**	**NS**	**0.08**	**NS**	**NS**	**NS**
D. Interactions						
A×B×C						

SEd±	**0.73**	**0.60**	**0.09**	**11.22**	**15.38**	**9.51**
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Treatments	**Grain yield (kg ha^{-1})**			**Straw yield (kg ha^{-1})**			**Harvest index (%)**		
	2020-21	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
A. Irrigation scheduling									
Two irrigations at CRI and Jointing stage	3731.66	3433.13	3582.40	6021.50	5571.90	5796.70	38.25	38.11	38.18
Three irrigations at CRI, Jointing and Booting stage	4175.83	3841.76	4008.80	6503.66	6019.54	6261.60	39.08	38.94	39.01
Four irrigations at CRI, Tillering, Booting and Milking stage	4564.16	4199.03	4381.60	6907.50	6394.81	6651.15	39.77	39.62	39.70
SEd±	**57.46**	**45.15**	**36.54**	**74.37**	**68.16**	**50.44**	**0.11**	**0.39**	**0.20**
CD at 5%	**159.52**	**125.34**	**84.26**	**206.45**	**189.21**	**116.31**	**0.31**	**1.08**	**0.46**
B. Moisture conservation practices									
Without mulching	3907.77	3595.15	3751.46	6122.00	5666.79	5894.39	38.91	38.76	38.84
Organic mulch @ 10 t ha-1 + Kaolin 6% spray	4406.66	4054.13	4230.40	6833.11	6324.04	6578.57	39.16	39.02	39.09
SEd±	**43.49**	**34.52**	**27.76**	**59.46**	**55.15**	**40.55**	**0.32**	**0.19**	**0.18**
CD at 5%	**106.41**	**84.48**	**60.49**	**145.50**	**134.95**	**88.35**	**NS**	**NS**	**NS**
C. Nutrient management									
100% RDF (150:60:40 kg ha^{-1} NPK)	4180.00	3845.60	4012.80	6541.33	6054.60	6297.97	38.94	38.79	38.86
85% RDF + FYM @ 5 t ha^{-1}	4289.16	3946.03	4117.60	6583.83	6093.58	6338.71	39.39	39.25	39.32
75% RDF + FYM @ 10 t ha^{-1}	4002.50	3682.30	3842.40	6307.50	5838.06	6072.78	38.77	38.63	38.70
SEd±	**57.47**	**46.47**	**36.94**	**85.16**	**79.80**	**58.35**	**0.28**	**0.32**	**0.21**

CD at 5%	**118.61**	**95.92**	**74.32**	**124.31**	**164.70**	**117.41**	**NS**	**NS**	**NS**
D. Interactions (A×B×C)									
SEd±	**140.76**	**113.83**	**90.48**	**208.60**	**195.47**	**142.93**	**0.70**	**0.78**	**0.52**
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table: 3 Effect of treatments on yield of wheat