~~Growth~~Performance, phenology, ~~yield, quality~~ and water relations in wheat (*Triticumaestivum* L.) ~~as influenced by~~Concerning moisture ~~regimes~~ and INM modules.

Abstract

A field experimenton wheat (*Triticumaestivum*L.) was carried out during two consecutive *rabi*seasons 2021-22 at the Crop Research Centre of SardarVallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India. The soil of the experimental field was sandy loam in texture, low in ~~organic~~ carbon and ~~available~~ nitrogen, but medium in ~~available~~ phosphorus and ~~available~~ potassium having a slightly alkaline pH (8.7) with an electrical conductivity of 0.327.We experimented with t~~T~~hree moisture regimes in main plots ~~namely~~, I_1: irrigation at an IW/CPE ratio of 0.7, I_2: irrigation at an IW/CPE ratio of 0.9, and I_3: five irrigations at critical stages (CRI, LT, LJ, F, and M) and six integrated nutrient management (INM) modules in subplots~~*viz*~~, N_1: control, N_2: 100% RDF (150:75:60 kg NPK/ha), N_3: 125% RDF, N_4: 50% RDF+PM ~~@~~ at2.5 t/ha, N_5: 50% RDF+PM ~~@~~ at2.5 t/ha+*Azotobacter*+PSB+KMB, N_6: 50% RDF+ PM ~~@~~ at2.5 t/ha, N_5: 50% RDF+PM ~~@~~ at2.5 t/ha+NPK consortia ~~were tested~~in split plot design with three replications. ~~On pooled basis of two years experimentation t~~The results showed that~~,~~the irrigation applied at critical stages (CRI, LT, LJ, F, and M) resulted in~~to~~significantly (P<0.05) tallest plants~~(79.6 cm)~~, more number of physiologically active leaves/pant ~~(5.64)~~at 50% flowering stage, days taken to 50% flowering ~~(85.9)~~, days taken to maturity ~~(142.1)~~, spike length ~~(11.5 cm)~~, grains weight/spike ~~(2.02 g)~~, grain yield ~~(48.7 q/ha)~~, protein content (11.1 %) in grains and crop water use 541.9mm~~)~~ over IW/CPE ratio of 0.7. While,the reverse trend was noticed for soil pH ~~(8.47)~~ and electrical conductivity ~~(0.359 dS/m)~~, beingmaximumunder the IW/CPE ratio of 0.7. Moreover, the highest water productivity was obtained with a 0.9 ratio followed by 0.7.In respect of INM modules, the tallest plants ~~(81.0 cm)~~, more ~~number of~~ days taken to 50% flowering ~~(87.2)~~, days taken to maturity,~~(143.1)~~and soil pH~~(8.51) was~~were noticed with N_3 treatment, which was significantly (P<0.05) higher over the rest of the treatments, except plant height, being *on par* with N_2 and N_6~~treatment~~and soil pH which did not show any significant variationduring both the years. While, the maximum number of physiologically active leaves/plant ~~(5.62)~~, grains weight/spike ~~(2.07 g)~~, protein content ~~(11.2%)~~ in grains, and electrical conductivity ~~(0.374 dS/m)~~were recorded under N_5. However, the physiologically active leaves/plant and grain weight/spike was significantly (P<0.05) superior over control and protein content in grains under N_1 and N_2~~both~~. Moreover, the longest spike ~~(11.4 cm)~~, grain yield ~~(51.0 q/ha)~~, crop water use, ~~(481.0 mm)~~ and water productivity ~~(6.38 kg/ha-mm)~~ w~~as~~ere registered with N_6, being significantly(P<0.05) superior over the control. Further, thistreatment outyielded control and RDF by 23.7 and 6.3 %, respectively.

Keywords: ~~Wheat, Moisture Regimes, INM Modules,~~ Biofertilizers, INM Modules, Moisture Regimes, Wheat.

1. Introduction

Wheat (*Triticumaestivum*L.)is the second most important food crop ~~of~~ inthe world, as well as India. It is cultivated under various growing conditions of soil and climate and plays a vital role in the food and nutritional security of the country. In India, it accounts for about14%~~percent~~ of the global wheat area (30.5 m ha) and 13%~~percent~~ of global wheat production (109.8 million tonnes). Water is considered ~~as~~ one of the most crucial inputs for agricultural production. Wheat is highly sensitive to water stress during crown root initiation and flowering stage. ~~The e~~Excessive irrigation ~~also~~ affects the growth and development adversely and consequently the grain yield. However, maintenance of proper moisture levels throughout the growing season is required to secure uninterrupted crop growth and more economic yield. Proper scheduling of irrigation is requiredduring the vegetative and reproductive phases of the crop to maintain the proper moisture for excellent growth and development of the crop in diversified climatic conditions. Irrigation frequency has a significant influence on the growth and yield of wheat.Wajid*et al.*(2002) reported that wheat crops produced the highest grain yield by applying proper moisture at all the definable growth stages. Wheat is generally grown in intensive cropping systems with the excessive use of inorganic fertilizers, especially nitrogenous (Yadav*et al.*, 2019). Increased application of chemical fertilizers can also increase the production, but continuous use of chemical fertilizers led to declining in partial factor productivity, and also disturbed the physio-chemical properties of soil, causing adverse effects on the environment and ~~impaired~~ impairingthe groundwater quality which causes health hazards in changing climate scenario and thus making fertilizer consumption uneconomical (Aulakh and Abhya, 2009).

An integrated nutrient management module~~s~~ to ~~maximising~~ maximizethe benefits from all potential sources of plant nutrients ~~in order~~ to keep soil fertility and plant nutrient supply at the optimum level for preserving the desired production (Kumar*et al.*, 2023).

~~Therefore, in recent year's~~Recentlythe use of organic manure along with biofertilizers gained priority over ~~the~~ inorganic fertilizers alone to meet the demand ~~of~~ foressential nutrients~~to~~ inthe wheat crop. Whereas, integration of organic sources, bio-fertilizers, and chemical fertilizers not only supply essential nutrients to the crop but also have some positive interactions leading to increased efficiency, restoration of soil health, and quality food production (Hafiz *et al.*, 2011). Organic manures, such as poultry manure and biofertilizers should be considered as ~~an~~ integral components and aid in the recovery of soil health in cropping systems by improving soil fertility and water holding capacity (Mahajan *et al.*, 2009).~~In the light of above facts,~~We investigated the response of wheat under judicious use of moisture regimes and efficient INM mode was studied in western up conditions.

2. MATERIALS AND METHODS

Experimental site:

The field experiment was conducted atthe Crop Research Centre (at a latitude of 29˚ 4' North, a longitude of 77˚ 42' East, and an elevation of 228 ~~metre~~ m above mean sea level) of SardarVallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India during two consecutive *rabi*season 2021-22 on sandy loam soil. The soil was low in organic carbon (0.34%) and available nitrogen (203.3 kg/ha), but medium in available phosphorus (20.8 kg/ha) andavailable potassium (223.0 kg/ha) having pH (8.7) withan electrical conductivity of 0.327. The soil of the experimental field was moist, ~~well~~ well-drained with uniform topography. The rainfall received during the crop period was 173.5 and 155.9 mm in 2021-22 and 2022-23, respectively.

Treatment description:

The experiment was laid out in a ~~split~~ split-plot design with three replications and 18 treatment combinations. The treatment comprised~~of~~ three moisture regimes *viz*, I_1: irrigation at an IW/CPE ratio of 0.7, I_2: irrigation at an IW/CPE ratio of 0.9, and I_3: five irrigation at critical stages (Crown root initiation, Late tillering, Late jointing, Flowering and milking stage) as main plotfactor and six INM modules~~*viz*~~, N_1: control, N_2: 100% RDF (150:75:60 kg NPK/ha), N_3: 125% RDF, N_4: 50% RDF+PM ~~@~~ at2,5 t/ha, N_5: 50% RDF+PM ~~@~~ at2.5 t/ha + *Azotobacter*+PSB+KMB, N_6: 50% RDF+PM ~~@~~ at2,5 t/ha, N_5: 50% RDF+PM ~~@~~ at2.5 t/ha+NPK consortiaas subplot factor.

Variety description:

The variety, DBW-187 (Karan Vandana) was taken for experimentation. This Variety was developed by ICAR- Indian Institute of Wheat and Barley Research Karnal, Haryana. It was notified in 2019 and recommended for commercial cultivation in NEPZ, mainly under irrigated timely sown conditions.It has an average maturity period of about 140-145 days and a potential yield of 60-65 q/ha.

Scheduling irrigation:

One pre-sowing irrigation (10 cm deep) was uniformly applied for proper germination of wheat crops in the entire field. For each irrigation water was applied ~~@~~ at 7 cm depth in an IW/CPE ratio of 0.7~~,~~ when the cumulative pen evaporation reading was reached at 100 mm (10 cm) and in I_2~~i e.,~~ IW/CPE ratio of 0.9 when the cumulative pen evaporation reached ~~at~~ 77.8 mm ~~(7.78 cm)~~, while in treatment I_3, irrigation water was applied at five critical stages (above 20-25 days intervals).The daily pan evaporation was recorded at the meteorological observatory of SVPUAT, Meerut during the crop growth period in the first and second years ~~both~~. The ~~of~~ IW/CPE ratio has been worked out as,

$$\mathrm{IW/CPE} = \frac{\text{Irrigarion water (mm)}}{\text{cumulative pen evaporation (mm)}}$$

The time of irrigation ~~were~~ was calculated ~~on the basis of~~ based onthe formula (Edward, 2006) given as under,

$$t = \frac{a \times d}{q}$$

Where,

t = time of application of irrigation (hour)

a = area of the plot to be irrigated (m^2)

d = depth of irrigation water (cm)

q = discharge of irrigation water ~~litre~~ liter/second

~~Discharge~~ The discharge of irrigation water was measured with the help of a 90˚ V notch, which was installed in the irrigation channel.

Description of manures and fertilizers:

The experimental soil was fertilized as per treatments, after laying out of the experimental field, poultry manure ~~@~~ at 2.5 t/ha was thoroughly mixed up to the top 15 cm soil depth, before one week of sowing. The quantity of poultry manure was used on the oven dry weight basis. The ~~recommended dose of~~ nitrogen, phosphorus, and potassium recommended doses were applied through urea, NPK (12:32:16), and muriate of potash. The amounts of NPK present in the various sources used in experimentation is given in Table 1.

Table 1: NPK Content present in the various sources of fertilizers

S. No.	Source	N (%)	P_2O_5 (%)	K_2O(%)
1.	Poultry Manure	3.0	2.6	1.4
2.	Urea	46	-	-
3.	NPK	12	32	16
4.	MOP	-	-	60

The wheat seeds~~@~~at100 kg/ha used for sowing receiving bio-fertilizers treatment were inoculated with*Azotobacter*, phosphorus solubilizing bacteria (PSB), potassium mobilizing bacteria (KMB), and NPK consortia, as per treatments. For the inoculation of bio-fertilizers, 10 % jaggery slurry was prepared by boiling the jaggery solution. The culture of various bio-fertilizers each ~~@~~ at20ml/kg seed ~~were~~ wasmixed in the cooled ~~jiggery~~ jaggeryslurry. The required quantity of seed was thoroughly mixed with the solution for uniform coating over the seeds; the inoculated seeds were dried in the shade and subsequently used for sowing in respective treatments during both ~~the~~ years.

Data recording and their analysis:

Plant height was recorded with the help of a meter scale, the yield was recorded in kg/plot and then converted into q/ha, protein content in grains as determined by modified-Kjeldahl method was multiplied by 5.73 to get total protein content, soil pH, and EC was determined with the help of glass electrode pH and EC meter in 1:2.5 soil: water suspension method (Richards, 1968) and Crop water use ~~was~~ werecalculated by adding contribution from different sources, *i.e.* water applied thought the irrigation, difference in moisture content at sowing and harvesting and effective rainfall and water productivity was calculated as the production of economic yield per unit of the total amount of water applied. For the pooled data, the mean of the ~~two~~ two-year data was ~~analysed~~ analyzedthrough the ~~analysis~~ Analysis of ~~variance~~ Variance (ANOVA) technique for~~split~~ split-plot design and presented at a 5% level of significance (P = 0.05).

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Results and Discussion

Growth

~~Perusal~~ A perusal of the pooled data presented in Table-2 ~~clearly~~ indicated that the plant height and physiologically active leaves/plant ~~was~~weresignificantly(P<0.05) affected by various moisture regimes and INM Modules.

The result showed that the highest mean plant height ~~(79.6 cm)~~ was recorded under the irrigation applied at critical stages, being statistically *on par* with I_2 and significantly (P<0.05) superior ~~over~~ tothe I_1 treatment. This might be due to the availability of an adequate supply of irrigation water at all the critical growth stages of crop growth, which induced rapid cell division and cell elongation and consequently ~~the~~ higher crop growth. These results are~~also~~ corroborated ~~with~~by~~the findings~~those of Carillo*et al.*(2011). Among theINM modules, the highest mean plant height ~~(81.0 cm)~~ was noted under the application of 125% RDF, which was statistically*on par* with treatments N_2 and N_6 but significantly (P<0.05) higher over the rest~~ of the treatments~~. This improvementin plant height might be attributed to the fact that a higher recommended dose of fertilizers resulted in the higher availability of nutrients in the soil forenhanced cell division, cell elongation, as well as various metabolic processes which were ultimately responsible for increased plant height. The results have got close conformity with the findings of Krishna *et al*. (2008).

The results showed that the highestpooled physiologically active leaves/plant ~~(5.73)~~ were recorded under the irrigation applied at five critical stages, which was significantly (P<0.05) superior overthe rest~~ of the treatments~~. This might be due to the proper moisture supply that increased the chlorophyll content in leaves and consequently increased the rate of photosynthesis.

Among the INM modules, the mean maximum physiologically active leaves/plant ~~(5.62)~~ were recorded in treatment N_5 which was *on par* with other treatments, except control. This might be attributed to better integration of chemical fertilizers with poultry manure and biofertilizers, however, poultry manure andbiofertilizers enhance~~s~~ the uptake of N and P for the plants which results in more synthesis of chlorophyll in the leaves. Similar results were also reported by Jan and Boswal (2015).

Phenology

T~~Perusal of t~~he mean data presented in Table-2~~clearly~~ indicates that the phenology of wheat was significantly(P<0.05) influenced by various moisture regimes and INM modules.

T~~Perusal of t~~he mean data showed that in the various moisture regimes, ~~the~~more~~(85.8and 143.1) number of~~ days were taken to attain~~at~~ 50% flowering and maturity under the irrigation applied at critical stages followed by ~~(83.6 and 140.1)~~under theirrigation applied at an IW/CPE ratio of 0.9 and wheat tooka minimum~~(81.6 and 136.3)~~ number of days to attain50% flowering and maturity.This delay~~ing~~ might be due to favo~~u~~rable plant growth conditions owing to better availability of soil moisture, which facilitates better crop growth and delayed its life cycle and alsoavoids forced maturity due to terminal heat (Ranjanna*et al*., 2017).

Among the INM modules, the maximum ~~(87.2 and 143.1)~~ number of days taken to attain~~at~~ 50 % flowering and maturity was found under the application of 125% RDF followed by N_2, N_4, N_6, and N_5, and the minimum~~(80.2 and 135.1)~~ was recorded under the control. Thismight be due to the more availability of nutrients, particularly nitrogen which promotes the vegetative growth stage of crops and balanced nutrition. Similar findings were ~~also~~observed by Meena*et al*., (2005).

Yieldattributes, yield, and protein content

The ~~results obtained from the present investigation on~~ yield attributes, protein, and yield of wheat (on pooled basis)were significantly (P<0.05) influenced by various moisture regimes and INM modules. The ~~data presented in the table indicated that the~~highest spike length~~ (11.5 cm)~~, grain~~s~~ weight/spike,~~ (2.02 g)~~ and grain yield ~~(48.7 q/ha)~~were recorded under the I_3 treatment which received irrigation at critical stages and was statistically *on par* with I_2,but significantly(P<0.05) superior over the I_1~~ (0.7 IW/CPE) treatment~~. The increase in yield attributes and yield of wheat in the present investigation might be due to adequate availability of moisture gained by the application of more ~~number of~~ irrigations throughout the growing season which inturn increased the plant biomass and proper development of sink along with better translocation of photosynthates towards sink. ~~Similar~~ A similar finding was observed by Thakur *et al*., (2000) and Niwas*et al*., (2019). The same trend was also noticed for protein content (%) in grains.

~~Among the INM modules, t~~The longest spike ~~(11.4 cm)~~ and grain yield ~~(51.0 q/ha)~~ was noticed underthe application of ~~50 % RDF + PM@ 2.5 t/ha + NPK consortia~~N_5. The spike length was statistically *on par* with treatments N_2, N_3, N_4, and N_5 but significantly (P<0.05) superior over control,while grains yield, being *on par* with treatments N_3, N_4, and $N_5$and significantly (P<0.05) superior over N_1 and N_2~~treatments~~. The more grains weight/spike ~~(2.07 g)~~ was registered under the treatment N_5, being *on* ~~per~~*par*with N_2, N_3, N_4, and N_6,but significantly (P<0.05) higher over the control. This increase might be ~~due to the fact that~~because, the integration of poultry manure and biofertilizers with a half dose of chemical fertilizers supplied the plant nutrients in adequate proportion at all the crop growth stages and increases nutrient use efficiency and water holding capacity for longer periods~~ of time~~, which increased the photosynthetic activities and translocated more ~~photosnthates~~photosynthatein the reproductive stage of crop growth, thereby enhance the yield attributes and yield of wheat. Similar results were also reported by Yadav*et al.* (2018). The maximum mean protein content (11.2 %) in grains was recorded under the treatment of N_5 which was statistically *on par* with N_3 and N_6 and significantly higher overthe rest~~ of the treatments~~. This ~~is~~ might be ~~due to the fact that~~becauseof the integration of poultry manure and biofertilizersalong with chemical fertilizer which resulted that poultry manure and biofertilizers~~increase~~ increasingthe nitrogen content in grains consequently ~~enhanced~~ enhancingthe protein content in grains.

Soil studies

~~Perusal of the mean~~The data in ~~the~~ Table-4 indicated that the electrical conductivity (dS/m)was slightly affected by various moisture regimes and INM modules. Under the various moisture regimes, the soil pH ~~(8.33)~~ and electrical conductivity ~~(0.336 dS/m)~~ ~~was~~were slightly reduced under the irrigation applied at critical stages followed by irrigation applied at IW/CPE ratios of 0.9 and 0.7. However, the maximum mean soil pH~~(8.47)~~ and electrical conductivity ~~(0.359 dS/m)~~w~~as~~ere recorded under the irrigation of the IW/CPE ratio of 0.7. This might be due to~~that~~thosefrequent irrigations at critical stages, which slightly reduces the soil pH and electrical conductivity. These findings are supported by Bhattacharyaya*et al.* (2008) and Pal *et al.* (2022). ~~Among the INM modules,~~Theminimum mean soil pH was recorded under the application of ~~50% RDF+PM @ 2.5 t/ha+NPK consortia treatment~~N_5. This is might due to owing the formation of organic acids during the decomposition of poultry manure. Our results are in line~~s~~with those of Kumara *et al.* (2013) and Singh (2019).

Crop water use

The total crop water use was calculated by adding contributions from different sources ofwater, *i.e.* water applied throughough~~t the~~ irrigation, the difference in moisture content at sowing and harvesting, and effective rainfall. It was directly related to the number of irrigation applied to relative treatments. The maximum amount ofcrop water use~~(541.9 mm)~~was recorded under the treatment which received irrigation at critical stages followed by I_2 and minimum water use was observed under I_1 treatment (Table-4).The treatment I_3~~had~~ received 26.8% more water compared to the I_1 treatment. This was mainly ~~due to thefact that~~because more frequent irrigation applied under I_3(at critical stages) maintains the optimum soil moisture throughout the growth period of the crop. Singh *et al.* (2015) and Niwas*et al.* (2023) also made similar observations in wheat atHisar (H.) and Kanpur (U.P.), respectively. Among the INM modules, the application of ~~50% RDF + PM @ 2.5 t/ha + *Azotobacter* + PBS + KMB~~N_5 in wheat showed the highest crop water use ~~(482.5 mm)~~ and it was higher ~~(1.8%)~~ compared to the control.

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Water productivity

Thewater productivity was calculated as the production of economic yield per unit of the total amount of water used. In the moisture regimes, the maximum mean water productivity ~~(5.94 kg/ha-mm)~~ was recorded under the irrigation applied at an IW/CPE ratio of 0.9 followed by 5.62 kg/ha-mm under the IW/CPE ratio of 0.7 and a minimumof 5.46 kg/ha-mm with irrigation at critical stages. This ~~is~~ might be ~~due to fact that~~because better grain yield obtained with a minimum amount of water applied resulted in more water productivity. ~~Similar~~ A similar finding was noted by Rajanna*et al.* (2017). Among the INM modules, the maximum water productivity (6.38 kg/ha-mm) was observed under the application of ~~50 %~~

RDF + PM @ 2.5 t/ha + NPK consortiaN_5 being *on par* with N_2, N_3, N_4, and N_5 but significantly (P<0.05)higher than the control. This is might be due to the fact thatbecausethe integration of poultry manure and biofertilizers along with chemical fertilizer produce more yield per unit of water use. The sSimilar results were reported by Liu *et al*. (2018).

Table 2: Effect of various moisture regimes and INM modules on growth, and phonology of wheat (pooled mean of 2021-22 and 2022-23)

Treatment	At 50 % flowering		Days taken to	
	Plant height (cm)	**Physiologically active leaves/plant**	**50 % flowering**	**Maturity**
Moisture regimes				
I_1	73.2	5.20	81.6	136.3
I_2	76.3	5.39	83.6	140.1
I_3	79.6	5.73	85.8	143.1
S.Em.±	0.8	0.03	0.5	1.1
C.D. (P= 0.05)	3.6	0.13	2.4	5.1
INM modules				
N_1	65.5	5.02	80.2	135.1
N_2	78.9	5.47	85.2	141.2
N_3	81.0	5.56	87.2	143.1
N_4	77.1	5.43	83.5	139.7
N_5	77.5	5.62	82.5	138.7
N_6	78.4	5.54	83.2	139.1
S.Em.±	1.0	0.07	0.5	1.1
C.D. (P= 0.05)	2.8	0.20	1.6	3.2

Table 3: Effect of various moisture regimes and INM modules on yield attributes, protein content, and yield of wheat (pooled mean 2021-22 and 2022-23)

Treatment	Spike length (cm)	Grains weight/spike (g)	Grain yield (q/ha)	Grains protein content (%)
Moisture regimes				
I_1	10.5	1.83	42.2	10.5
I_2	10.7	1.94	44.9	10.7
I_3	11.5	2.02	48.7	11.1
S.Em.±	0.2	0.03	0.87	0.11
C.D. (P= 0.05)	0.9	0.13	3.90	0.50
INM modules				
N_1	9.4	1.46	22.8	10.0
N_2	11.0	1.98	48.0	10.8
N_3	11.2	2.03	50.3	11.0
N_4	11.1	2.01	48.9	10.8
N_5	11.3	2.07	50.6	11.2
N_6	11.4	2.04	51.0	11.0
S.Em.±	0.2	0.03	0.85	0.12
C.D. (P= 0.05)	0.6	0.09	2.45	0.35

Table 4: Effect of various moisture regimes and INM modules on soil pH, electric conductivity (dS/m), physiological efficiency, crop water use, and water productivity of wheat (pooled mean 2021-22 and 2022-23)

Treatment	Soil pH	Electrical conductivity (dS/m)	Crop water use (mm)	Water Productivity (kg/ha-mm)
Moisture regimes				
I_1	8.47	0.359	427.3	5.62
I_2	8.41	0.354	467.1	5.94

I_3	8.33	0.336	541.9	5.46
S.Em.±	0.08	0.003	1.5	0.11
C.D. (P= 0.05)	NS	0.013	6.6	NS
INM modules				
N_1	8.39	0.297	474.0	2.90
N_2	8.50	0.345	475.5	6.06
N_3	8.51	0.357	479.6	6.29
N_4	8.43	0.364	480.0	6.11
N_5	8.34	0.374	482.5	6.31
N_6	8.25	0.362	481.0	6.38
S.Em.±	0.12	0.005	2.2	0.11
C.D. (P= 0.05)	NS	0.013	6.5	0.33

4. CONCLUSION

~~On the basis oftwo years experimentation, it may be concluded that t~~The irrigation applied at critical stages along with 50% RDF through chemical fertilizers and the rest through organic manures along with biofertilizersin wheat seems to be best as they improved the growth, phenology, yield attributes, yield and protein content, and crop water use, witha slight reduction in soil pH and electrical conductivity than rest of the treatment combinations. Although, the highest water productivity was achievedunder the irrigation applied at an IW/CPE ratio of 0.9.

5. REFERENCES:

Comment [es1]: MUST BE UPDATED as 30% (6 out of 20) of the listed references were published in the past five years. The percentage has to increase to at least 35-40%. Old and lack of updated references might negatively influence the importance of the study.

Anlakh, M.S. and Adhya, T.K. (2005). Impact of agricultural activities on emission of greenhouse gases-Indian perpective. Indian Society of Soil Science pp. 319-335.

Bhattacharyya, R., Kundu, S., Pandey, S. C., Singh, K. P. and Gupta, H. S. (2008). Tillage and irrigation effects on crop yields and soil properties under the rice–wheat system in the Indian Himalayas. *Agricultural water management* ***95***(9), 993-1002.

Carillo, P., Annunziata, M. G., Pontecorvo, G., Fuggi, A., & Woodrow, P. (2011). Salinity stress and salt tolerance. *Abiotic stress in plants-mechanisms and adaptations*, *1*, 21-38.

Hafiz, M.H., Khaliq, A.,Ashfaq, A., Aslam, M., Ali, M., Farshad M.W. and Laghari, K.Q. (2011). Influence of different organic manures on wheat productivity. *International Journal of Agriculture Biology* **13**(1): 139

Jan, K. andBoswal, M.V. (2015). Effect of bio-fertilizer and organic fertilizer on physiological characteristics of bread wheat (*Triticumaestivum* L.). *International Journal of scientific research and management* 3(2): 2073-89.

Krishna, A. Biradarpatil, N.K. and Channappayoundar, B.B. (2008). Influence of System of Rice Intensification (SRI) cultivation on seed yield and quality. *Karnataka Journal of Agricultural Science*, **21**(3): 369-372.

Kumara, B.H., Antil, R.S. and Dev, R. (2013). Long term effect of nutrient management on soil health and crop productivity under pearl millet-wheat cropping system. *Indian Journal of Fertilizers* 9(12): 86-97.

Kumar, S., Agrawal, S., Jilani, N., Kole, P., Kaur, G., Mishra, A. ... & Tiwari, H. (2023). Effect of integrated nutrient management practices on growth and productivity of rice: A review.*The Pharma Innovation Journal*; **12** (5): 2648-2662.

Lai, Y., Pringle, M. J., Kopittke, P. M., Menzies, N. W., Orton, T. G. and Dang, Y. P. (2018). An empirical model for prediction of wheat yield, using time-integrated Landsat NDVI. *International journal of applied earth observation and geoinformation*, *72*, 99-108.

Mahajan, A., & Gupta, R. D. (Eds.). (2009). *Integrated nutrient management (INM) in a sustainable rice—wheat cropping system*. Dordrecht: *Springer Netherlands*. pp 139–168, Dordrecht. https://doi.org/10.1007/978-1-4020-9875-8_10

Meena, M.C., Swarup, A., Wanjari, R.H., Ravankar, H.N., Mishra, B., Saha, M.N. and Sarap, P.A. (2005). Long term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under sub-humid and semi-arid tropical India. *Field Crops research* **93**(2-3): 232-241.

Niwas, R., Verma, V.K., Singh, D., Kumar, K., Tiwari, K. and Sachan, R. (2023). Studies on irrigation scheduling, moisture conservation practices and nutrient management on performance of wheat (*Triticumaestivum* L.). *International Journal of Environment and Climate Change***13**(2): 134-142.

Pal, S., Kumar, S., Kumar, P., Singh, A. and Gangwar, H. K. (2020). Effect of moisture regime on IW/CPE ratio on soil properties, yield and water use efficiency of wheat crop (Triticumaestivum L.). *International Journal of Current Microbiology and Applied Sciences**9*(3), 2499-2506.

Rajanna, G.A., Dhindwal, A.S. and Nanwal, R.K. (2017). Effect of irrigation scheduling on plant- water relations, root, grain yield and water productivity of wheat

(*TriticumaestivumL.*) under various crop establishment techniques. *Cereal Research Communication* **45**(1): 166-177.

Richard, L.A. (1968). Diagnosis and improvement of saline and alkali soil. *United states Department of Agronomy*, Hand Book No. 60 Oxford and IBH publishing Company New York.

Singh, K., Dhindwal, A.S., Dhaka, A.K., Sewhag, M. and Pannu, R.K. (2015). Water use pattern and productivity in bed planted wheat (Triticumaestivum) under varying moisture regimes in shallow water table conditions. *Indian Journal of Agricultural Sciences***85** (8): 1080–84.

Singh, S.P. (2019). Effect of integrated nutrient management of wheat (*Triticumaestivum*L.) yield, nutrient uptake and soil fertility status in alluvial soil. *Indian Journal of Agricultural Sciences***89**(6): 929–33.

Wajid, A., Hussain, M., Maqsood, A., Ahmad and Awais, M. (2002). Influence of sowing dateandirrigationlevelsongrowthandgrainyieldofwheat.*PakistanJournalofAgricultural Science***39**(1):22-24.

Yadav, H.K. (2019). Effect of irrigation level and moisture conserving polymers ongrowth, productivity and profitability of wheat. *Indian Journal of Agricultural Sciences***89**(3):509-514.

Yadav, K., Singh, S., and Kumar, V. (2018). Effect of integrated nutrient management on soil fertility and productivity on wheat crop. *Journal of Experimental Agriculture International*, **24**(2): 1-9.