

Original Research Article

Crop Phenology, Growth Indices and Yield of Wheat as Influenced by Different Establishment and Moisture Conservation Practices under Limited Irrigated Conditions

Abstract

To find out best crop establishment method, and to evaluate the effect of moisture conservation practices on phenology, growth indices and grain yield of wheat under limited irrigated conditions a field experiment was conducted at the Research Farm of CCS Haryana Agricultural University, Hisar during the *Rabi* seasons of 2019-20 and 2020-21. CCS Haryana Agricultural University, Hisar is situated 29°10' N latitude and 75° 46' E longitude with an elevation of 215.2 meters above mean sea level in the semi-arid and sub-tropical zone. The experiment consisted of twenty four treatment combinations comprising three establishment methods *i.e.* Conventional Tillage (CT), Zero Tillage (ZT) and Bed Planting (BP) and two irrigation levels *i.e.* I₁-one irrigation applied at crown root initiation stage (I₁) and I₂-two irrigation applied at CRI and booting stages as main plot treatments and four moisture conservation practices *i.e.* M₀-no mulch, M₁-mulch (pearl millet straw @ 4 tonnes ha⁻¹), M₂- antitranspirant (kaolin @ 6% w/v) and M₃- mulch (pearl millet straw @ 4 tonnes ha⁻¹) + antitranspirant (kaolin @ 6% w/v) as sub-plots treatments. The experiment was conducted in split split-plot design with three replications. The results revealed that days taken to booting, heading and physiological maturity did not influence significantly by crop establishment methods. Crop took more days to attain booting (79.64 and 77.89), heading (90.33 and 88.08) and physiological maturity (138.86 and 137.42) stages when two irrigations were applied to the crop as compared to one irrigation during 2019-20 and 2020-21, respectively. Among moisture conservation practices, treatment M₃ took significantly higher numbers of days for booting (80.24 and 79.06), heading (91.00 and 88.39) and physiological maturity (140.39 and 138.72) stages as compared to M₀ but statically at par with M₁ and M₂. The growth indices *i.e.* crop growth rate and relative growth rate are significantly higher in BP, two irrigation levels and M₃ during 2019-20 and 2020-21, respectively. The maximum grain yield of wheat was recorded when crop was sown by bed planting method of crop establishment (4873 and 4423 kg ha⁻¹) as compared to ZT and CT during both the years. The grain yield was significantly higher with two irrigations levels (4,880 and 4,465 kg ha⁻¹) as compared to one irrigation during both the years. Treatment M₃ (4,879 and 4,468 kg ha⁻¹) produced significantly higher grain yield as compared to other treatments during 2019-20 and 2020-21, respectively.

Keywords: Wheat, Establishment, Irrigation Levels, Moisture Conservation, Phenology, Growth Indices and Grain Yield

1. INTRODUCTION

Wheat is one of the most important cereal crops of the world on account of its wide adaptability to cultivation under different agro-climatic and soil conditions. In India, it is the second most important source of staple food after rice. In India, area, production and average yield of wheat is 31.76 mha, 108.75 mt and 34.24 qha⁻¹, respectively during 2020-21. In Haryana, it is grown over an area of 2.52 mha with a production of 12.15 mt and productivity of 48.22qha⁻¹ during 2020-21 (ICAR-IIWBR, 2020-21). Wheat is usually planted either by drilling closely spaced rows apart on the flat bed or by broadcasting the seed on a levelled soil surface and then incorporating it by means of shallow tillage operations. Real challenges for today's Indian agricultural system are resource fatigue with stagnating productivity and profitability, decreasing human resources and their rising costs and socioeconomic changes (Kumar *et al.*, 2013). The new tillage and crop establishment technologies like minimum, zero till and furrow irrigated raised broad bed could answer the saving energy, resources and increasing yield of different wheat-based cropping systems (Singh *et al.*, 2013). In this sense, alternative best crop management options like zero tillage and beds have demonstrated potential benefits on crop yield and profits while saving water, energy and restoring soil degradation across diverse ecologies (Das *et al.*, 2014).

Wheat is highly sensitive to water stress during the crown root initiation Crown Root Initiation stage (CRI) and flowering stage and ultimately decrease the yield. Thus, timing the length of irrigation interval with the stages of crop growth might bring about a reduction in the number of irrigations and results in an economic crop yield. In principle, irrigation should take place while the soil water potential is still high enough to enable soil supply water fast enough to meet the local atmospheric demands without placing the plants under stress that would reduce yield and quality of crop. Singh *et al.* (2017) reported that the application of two irrigations at tillering and flowering stage (I₂) resulted in significant increase in Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Leaf Area Index (LAI) than no irrigation (I₀) and one irrigation (I₁) treatments during both the years.

Mulching has been proved to be useful in conserving moisture and increasing productivity of wheat. Straw mulch also provides benefit in terms of increasing infiltration rate, lowers the temperature, and improves fertilizer availability and increase crop yield (Singh *et al.*, 2011).

Mulches enhanced soil water status and improved growth and yield, which subsequently reducing runoff and evaporation losses. Angbabu *et al.* (2007) reported that the combined application of straw mulch at the rate of 6 t ha⁻¹ + kaolin spray at @ 6.0% w/v significantly influenced LAI, Crop Growth Rate (CGR and Net Assimilation Rate (NAR) during both the years of investigation. With these leads, the present investigation was formulated to study the effects of crop establishment methods, irrigation schedule and moisture conservation practices on the performance of wheat in terms of phenology, growth indices and grain yield under semi-arid conditions.

Materials and Methods

The field experiments were conducted at the Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar during the *Rabi* seasons of 2019-20 and 2020-21. The experiment consisted of twenty four treatment combinations comprising three establishments methods *i.e.* Conventional Tillage (CT), Zero Tillage (ZT), and bed planting (BP) and two irrigation levels *i.e.* I₁- one irrigation applied at Crown Root Initiation (CRI) and I₂- two irrigation applied at CRI and booting stages as main plot treatments and four moisture conservation practices *i.e.* M₀ - no mulch, M₁- mulch (pearl millet straw @ 4 tonnes ha⁻¹), M₂ - antitranspirant (kaolin @ 6% w/v) and M₃- mulch (pearl millet straw @ 4 tonnes ha⁻¹) + antitranspirant (kaolin @ 6% w/v) as sub-plots treatments. The experiment was conducted in split split-plot design with three replications. The soil of the experiment field was sandy loam in texture, slightly alkaline in reaction and pH of 7.6, low in organic carbon and available nitrogen, medium in available phosphorus, and high in available potassium. The crop was sown in the second week of November and the last week of November during 2019-20 and 2020-21, respectively. Fertilizer doses of 150 kg N, 60 kg P₂O₅ and 40 kg K₂O ha⁻¹ was applied as per the recommendation. Half dose of N and full dose of P and K were applied at the time of sowing while the remaining half dose of N applied to the crop at first irrigation. Agronomic practices, *i.e.* weeding, hoeing and plant protection measures were carried out as per recommendations at appropriate times. Data were recorded on days taken to emergence, days taken to booting, days taken to heading, days taken to physiological maturity, crop growth rate, relative growth rate, and grain yield as per the standard procedure. Data collected during the study were statistically analyzed by using the technique of analysis of variance (ANOVA) described by Cochran and Cox (1959).

Results and Discussion

The effect of crop establishment methods, irrigation schedules, and moisture conservation practices on days taken to the emergence, days taken to booting, days taken to heading, and days taken to physiological maturity stages of wheat are presented in Table 1 and illustrated in figures 1

and 2. The data indicate that the crop establishment methods, irrigation schedules and moisture conservation practices did not influence emergence of wheat during both the years. Days taken to the booting, heading and physiological maturity stages of wheat did not influence by crop establishment methods during both the years. The data indicate that the days taken to the booting, heading and physiological maturity stages of wheat differed significantly by irrigation levels. At booting stage, significantly more days were taken by the crop in I₂ treatment (79.64 and 78.61) as compared to I₁ (78.81 and 75.64) during 2019-20 and 2020-21, respectively. More days were taken for heading by the crop in I₂ treatment (90.33 and 88.08) which were significantly higher than I₁ (88.83 and 86.11) during 2019-20 and 2020-21, respectively. As well as significantly more days were taken by the crop in I₂ treatment (138.86 and 137.42) to attain the physiological stage as compared to days taken in I₁ (136.83 and 135.14) during both the years, respectively. Under higher levels of irrigation, the longer reproductive phase of crop growth and longer crop duration has been also reported by many workers (Zabihullah, 2020; Kumar *et al.*, 2018; Ngwako and Mashiq, 2013; Dhaka *et al.*, 2006). Under higher levels of irrigation, the longer reproductive phase of crop growth and longer crop duration has been also reported by Kumar *et al.* (2018).

Among the moisture conservation practices, data indicate that treatments M₃ (80.24 and 79.06) and M₁ (79.33 and 76.89) significantly took more days for the booting stage as compared to M₂ (78.91 and 76.61 days) and M₀ (78.41 and 74.50 days) during 2019-20 and 2020-21, respectively. Also, among the moisture conservation treatment, M₃ (91.00 and 88.39) and M₁ (90.00 and 87.44) significantly took more days for the heading stage than M₂ (89.56 and 86.89 days) and M₀ (87.78 and 85.67 days) during 2019-20 and 2020-21, respectively. As well as, M₃ (140.39 and 138.72) and M₁ (138.33 and 136.94) significantly took more days to attain the physiological maturity stage than M₂ (137.33 and 135.72 days) and M₀ (135.33 and 133.72 days) during both the years, respectively. Whereas, M₀ (no mulch) took less days for the booting, heading and physiological maturity stages during both the years.

The data on Crop Growth Rate (CGR) are presented in Table 1 showed that there was no significant difference in CGR due to crop establishment methods at 0-30 and 31-60 days of crop growth during both the years. Maximum CGR was recorded under bed planting method of crop establishment (4.30 and 4.05 g dm⁻² day⁻¹) at 31 to 60 days of crop growth, which was significantly higher than ZT (4.22 and 3.96 g dm⁻² day⁻¹) but it was statically at par with CT (4.26 and 4.00 g dm⁻² day⁻¹) during 2019-20 and 2020-21, respectively. A similar trend was also observed by Singh (2017). Among the irrigation levels, CGR differed significantly due to irrigation levels at 91-120 DAS and 121 DAS and at harvest. At 91-120 DAS, maximum CGR (2.44 and 1.99 g dm⁻² day⁻¹) was recorded in the treatment I₂ (two irrigation were applied to the crop) which was significantly higher over one

irrigation (I_1) (2.24 and 1.93 g dm⁻² day⁻¹) during 2019-20 and 2020-21, respectively. Similar trends was also noticed at 120 DAS- at harvest stage during both the years. These results are in conformity with the findings of Vishuddha *et al.* (2014) and Kumar *et al.* (2015) who also reported the maximum values of growth indices under more number of irrigation. Among the moisture conservation practices, at 61-90 DAS, application of straw mulch and antitranspirant (M_3) recorded significantly higher CGR (4.33 and 4.07 g dm⁻² day⁻¹) as compared to all other treatments, *i.e.* M_0 (4.19 and 3.92 g dm⁻² day⁻¹), M_2 (4.26 and 4.00 g dm⁻² day⁻¹), and M_1 (4.28 and 4.01 g dm⁻² day⁻¹) during 2019-20 and 2020-21, respectively. Similar trends was also recorded at 91-120 and 121 DAS to harvest. Brahma *et al.* (2007) obtained similar results and reported that kaolin contributed to enhanced growth indices. Wairagade *et al.* (2020) recorded significantly higher CGR and RGR under the application of wheat straw mulch over control.

Data of RGR influenced by different treatments at various stages are given in Table 1. The data revealed that RGR attained maximum value between 0-30 and 31-60 DAS stages and then declined consistently till crop maturity during both the years of study. However, there was no significant differences in RGR at 0-30 and 31-60 DAS due to crop establishment methods during both the years. Maximum RGR was observed with Bed Planting method (1.44 and 1.38 g/g/day) which was significantly higher than ZT (1.42 and 1.36 g/g/day) but statically at par with CT (1.43 and 1.37 g/g/day) during 2019-20 and 2020-21, respectively. Singh (2017) also reported similar results. The data on RGR presented in Table 3 showed that RGR not influence RGR by irrigation level significantly up to 90 DAS stage during both the years of experimentation. However, at 91-120 DAS, application of two irrigations (I_2) recorded significantly higher values of RGR (0.84 and 0.64 g/g/day) than one irrigation applied at CRI stage (I_1) (0.75 and 0.61 g/g/day) during 2019-20 and 2020-21, respectively. These results are in conformity with the findings of Vishuddha *et al.* (2014) and Kumar *et al.* (2015) who also reported the maximum values of growth indices under higher levels of irrigation. Among the moisture conservation practices, there was no significant differences in RGR at 0-30 DAS during both the years. At 61-90 DAS, M_3 recorded significantly higher CGR (1.44 and 1.38 g/g/day) over all other treatments *i.e.* M_0 (1.39 and 1.34 g/g day), M_2 (1.41 and 1.36 g/g day) and M_1 (1.42 and 1.36 g/g/day) during 2019-20 and 2020-21, respectively. Similar trends was also recorded at 91-120 and 121 DAS to harvesting stage during both the years. Patil *et al.* (2014) also reported that among moisture stress management practices, SH + mycorrhizae + KCl spray + kaolin spray recorded significantly highest growth indices, viz. LAI, CGR and RCG over no-management treatment. Brahma *et al.* (2007) also reported that kaolin contributed to enhanced growth indices. Wairagade *et al.* (2020) found significantly higher CGR and RGR under the application of wheat straw mulch treatment over control. In general, the grain yield was recorded higher during 2019-20 as

compared that of 2019-20. The Maximum grain yield of wheat was recorded when crop sown by Bed planting method (4,873 and 4,423Kg ha⁻¹) which was significantly higher as compared to Zero Tillage sowing (4,645 and 4,220 Kg ha⁻¹). Although, the differences between BP and CT (4,751 and 4,330 Kg ha⁻¹) were non-significant during 2019-20 and 2020-21, respectively. Similar trends have been observed by Singha *et al.* (2018), Kumar *et al.* (2018), and Singh *et al.* (2019). Sagar *et al.* (2017) also reported higher grain yield of wheat in bed planting than another crop establishment. Higher grain yield with bed planting of wheat has been also reported by Thind *et al.* (2010).

Grain yield was significantly influenced by different levels of irrigations. The higher grain yield of wheat (4,880 and 4,465 Kg ha⁻¹) was obtained in I₂ treatment (two irrigation) which was significantly higher than I₁ treatment (4,633 and 4,184 Kg ha⁻¹) during 2019-20 and 2020-21, respectively. The results are in close conformity with the results reported by Singh and Katiyar (2014), Sepat *et al.* (2015), Singh *et al.*, 2018; Kumar *et al.*, 2018. Kaur *et al.* (2018) also noticed that the higher grain yield with higher level of irrigations.

Among moisture conservation practices, maximum grain yield of wheat (4,879 and 4,468 Kg ha⁻¹) was recorded in the treatment M₃ (when mulch and antitranspirant were applied to the crop) which was significantly higher over M₀ (4,589 and 4,154 Kg ha⁻¹) but statistically at par with M₁ (4,785 and 4,341 Kg ha⁻¹) and M₂ (4,772 and 4,333 Kg ha⁻¹) during 2019-20 and 2020-21, respectively. Al-Amin *et al.* (2017) also noticed that the higher grain yield of wheat was recorded from the treatment when straw mulch was applied at the rate 6 tha⁻¹ while the lowest grain yield was recorded in control. This may occur due to the different environmental factors and cultural management practices.

Table 1: Effect of Different Crop Establishment Methods and Moisture Conservation Practices on Phenology Stages and Grain Yield of Wheat under Limited Irrigated Conditions.

Treatments	Days taken to						Grain Y		
	Emergence		Booting		Heading		Physiological Maturity		(kg ha ⁻¹)
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20
Crop Establishment Methods									
CT	6.35	7.76	79.71	77.29	90.13	87.92	138.63	137.08	4,751
ZT	6.24	6.99	78.63	76.00	89.00	86.08	136.50	135.00	4,645
BP	6.25	7.53	79.33	77.00	89.63	87.29	138.42	136.75	4,873
SEm±	0.10	0.14	0.30	0.84	0.49	0.65	0.70	0.77	46
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	145
Irrigation Schedules									
I ₁	6.27	7.41	78.81	75.64	88.83	86.11	136.83	135.14	4,633
I ₂	6.29	7.45	79.64	77.89	90.33	88.08	138.86	137.42	4,880
SEm±	0.05	0.09	0.21	0.69	0.40	0.53	0.57	0.63	37.51

CD at 5 %	NS	Ns	0.73	2.17	1.25	1.67	1.81	1.98	118
Moisture Conservation Practices									
M ₀	6.00	7.17	78.41	74.50	87.78	85.67	135.33	133.72	4,589
M ₁	6.50	7.41	79.33	76.89	90.00	87.44	138.33	136.94	4,785
M ₂	6.02	7.32	78.91	76.61	89.56	86.89	137.33	135.72	4,772
M ₃	6.19	7.02	80.24	79.06	91.00	88.39	140.39	138.72	4,879
SEm±	0.10	0.13	0.44	0.66	0.24	0.27	0.13	015	48
CD at 5 %	NS	NS	1.27	1.88	0.70	0.77	0.39	0.44	136

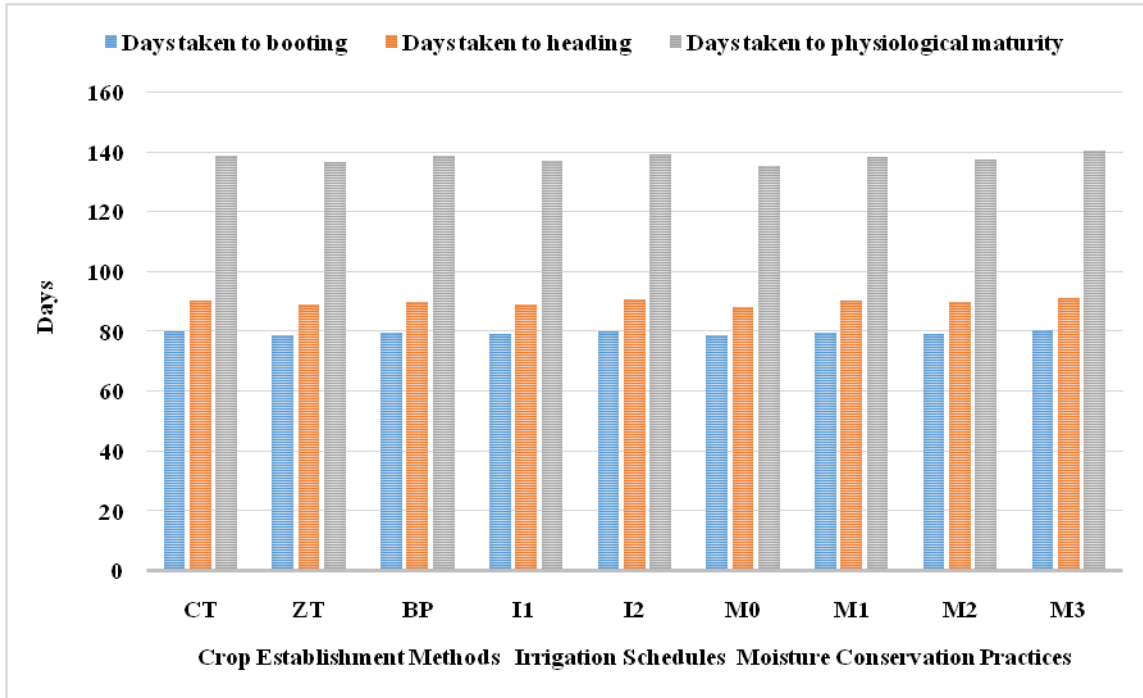


Fig. 1. Phenology of Wheat Crop as Influenced By Crop Establishment Methods, Irrigation Schedules and Moisture Conservation Practices in Wheat Crop during 2019-20

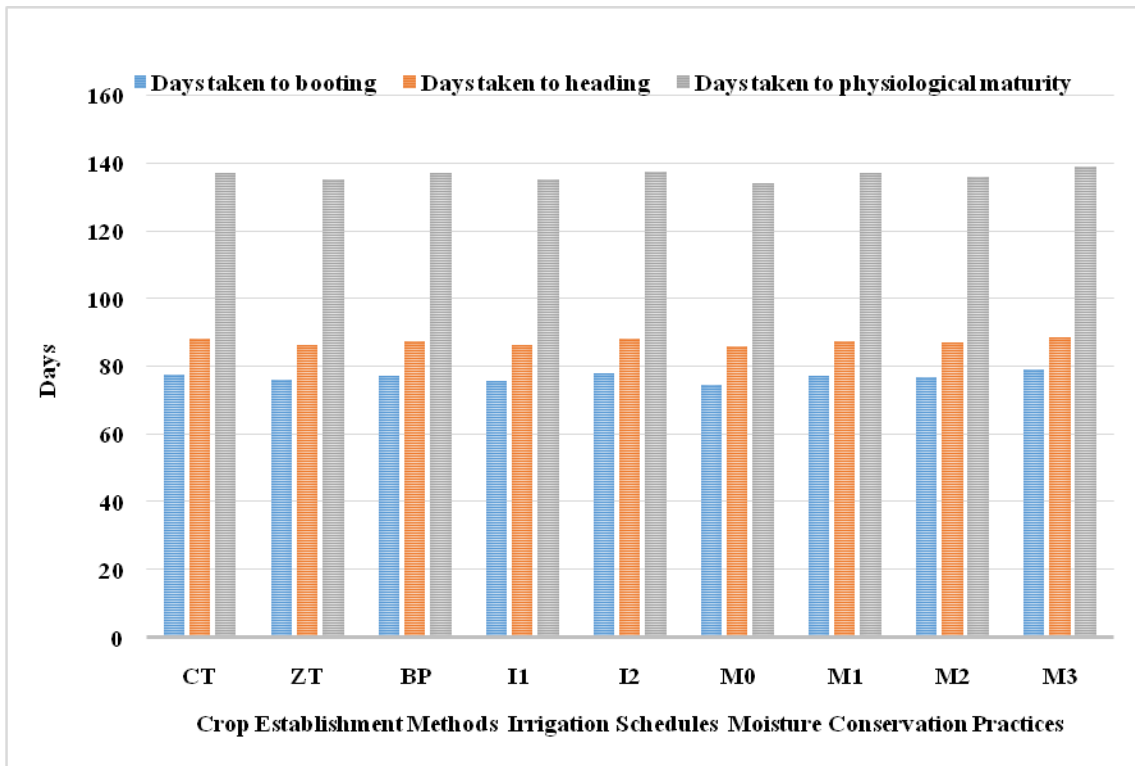


Fig. 2. Phenology of Wheat Crop as Influenced by Crop Establishment Methods, Irrigation Schedules and Moisture Conservation Practices in Wheat Crop during 2020-21

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Table 2: Effect of Different Crop Establishment Methodsdifferent crop establishment methods and Moisture Conservation Practicesmoisture conservation practices on Crop Growth Ratecrop growth rate (CGR) (g/m²/day) at Different Stagesdifferent

Treatments	Crop Growth Rate (CGR) (g/m ² /day)									
	At 0-30 DAS period		At 31-60 DAS period		At 61-90 DAS period		At 91- 120 DAS Period		At 121 DAS – harvest period	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Crop Establishment Methods										
CT	0.134	0.116	2.08	1.92	4.25	3.97	2.34	1.96	1.99	1.86
ZT	0.131	0.105	2.06	1.89	4.21	3.96	2.19	1.93	1.96	1.82
BP	0.139	0.117	2.13	1.94	4.29	4.04	2.55	2.01	2.14	1.91
SEm±	0.006	0.006	0.01	0.01	0.02	0.02	0.06	0.02	0.04	0.02
CD at 5 %	NS	NS	NS	NS	0.05	0.07	0.20	0.05	0.12	0.06
Irrigation Schedules										
I ₁	0.136	0.113	2.10	1.94	4.24	3.96	2.26	1.94	1.93	1.83
I ₂	0.133	0.112	2.10	1.90	4.26	4.02	2.46	2.00	2.08	1.90
SEm±	0.005	0.005	0.01	0.01	0.01	0.02	0.05	0.01	0.03	0.02
CD at 5 %	NS	NS	NS	NS	NS	NS	0.16	0.04	0.10	0.05
Moisture Conservation Practices										
M ₀	0.131	0.113	1.99	1.84	4.19	3.91	2.14	1.90	1.85	1.74
M ₁	0.135	0.117	2.11	1.93	4.26	4.00	2.36	1.97	2.04	1.88
M ₂	0.133	0.110	2.10	1.91	4.25	3.99	2.38	1.96	2.03	1.87
M ₃	0.139	0.110	2.15	2.00	4.31	4.06	2.56	2.04	2.19	1.97
SEm±	0.004	0.004	0.02	0.02	0.02	0.02	0.06	0.02	0.04	0.03
CD at 5 %	NS	NS	0.06	0.06	0.04	0.05	0.17	0.06	0.12	0.08

stages of Wheatwheat under Limited Irrigated Conditionslimited irrigated conditions

Table 3: Effect of Different Crop Establishment Methodsdifferent crop establishment methods and Moisture Conservation Practicesmoisture conservation practices on Relative Growth Rate (RGR) (g/g/day) at Different Stagesdifferent stages of Wheatwheat under Limited Irrigated Conditionslimited irrigated conditions.

Treatments	Relative Growth Rate (RGR) (g/g/day)									
	At 0- 30 DAS Period		At 31- 60 DAS Period		At 61-90 DAS Period		At 91- 120 DAS Period		At 121 DAS- harvest Period	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Crop Establishment Methods										
CT	0.071	0.062	0.81	0.72	1.41	1.36	0.80	0.62	0.66	0.60
ZT	0.070	0.062	0.80	0.71	1.40	1.35	0.73	0.61	0.63	0.58
BP	0.070	0.067	0.81	0.74	1.42	1.38	0.87	0.64	0.72	0.64
SEm±	0.001	0.002	0.005	0.01	0.004	0.01	0.03	0.01	0.02	0.01
CD at 5 %	NS	NS	NS	NS	0.014	0.02	0.08	0.03	0.05	0.03
Irrigation Schedules										
I ₁	0.070	0.063	0.81	0.73	1.41	1.36	0.76	0.61	0.63	0.58
I ₂	0.070	0.064	0.81	0.71	1.42	1.37	0.84	0.64	0.71	0.62
SEm±	0.001	0.001	0.004	0.01	0.004	0.01	0.02	0.01	0.01	0.01
CD at 5 %	NS	NS	NS	NS	NS	NS	0.06	0.02	0.04	0.03
Moisture Conservation Practices										
M ₀	0.070	0.063	0.78	0.67	1.38	1.34	0.71	0.58	0.58	0.53
M ₁	0.070	0.064	0.81	0.73	1.42	1.36	0.80	0.62	0.68	0.61
M ₂	0.068	0.062	0.80	0.71	1.41	1.36	0.81	0.63	0.67	0.60
M ₃	0.071	0.065	0.83	0.77	1.44	1.38	0.89	0.67	0.75	0.66

SEm±	0.002	0.001	0.005	0.01	0.004	0.01	0.02	0.01	0.02	0.02
CD at 5 %	NS	NS	0.014	0.03	0.011	0.01	0.07	0.03	0.06	0.04

Put the full meaning of abbreviations as foot note e.g. DAS below each table

Conventional Tillage (CT)

Zero Tillage (ZT)

Bed Planting (BP) Crop Growth Rate (CGR) Net Assimilation Rate (NAR)

Leaf Area Index (LAI)

Relative Growth Rate (RGR)

Day After Sowing (DAS)

Crown Root Initiation (CRI)

Quintal per Hectare (q ha)

Million per Hectare (m ha)

No irrigation (I₀)

One irrigation (I₁)

Critical Difference (CD)

Per Cent (%)

Seed Hardening (SH)

Million per Tonnes (m. t)

Standard Error of Mean (SEm)

et alii; (co-authors)) (*et al.*)

Id est (that is) (i.e.)

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Conclusion

Bed planting method of sowing was performed better in terms of phenology, growth indices and yield among different crop establishment methods *i.e.* Zero tillage and Conventional tillage sowing. Wheat crop perform better when two irrigations were applied to the crop at Crown Root Initiation (CRI) and Booting stage as compared to only one irrigation applied to the crop at CRI stage. Under limited irrigation conditions, application of mulch and/or spray of anti-transpirant (kaolin) improved the phenology, growth indices and yield of wheat crop.

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