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

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

To find out the 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 Wheat and Barley Section, Department of Genetic and Plant Breeding, 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) as main plot and two irrigation levels *i.e.* I_1-one irrigation applied at crown root initiation stage (I_1) and I_2-two irrigation applied at CRI and booting stagess as sub-main plot treatments and four moisture conservation practices *i.e.* M_0-no mulch, M_1-mulch (pearl millet straw @ 4 tonnes ha^{-1}), M_2- antitranspirant (kaolin @ 6% w/v) and M_3- mulch (pearl millet straw @ 4 tonnes ha^{-1}) +

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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 M_3 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 M_0 but statically at par with M_1 and M_2. The growth indices *i.e.* crop growth rate and relative growth rate are significantly higher in BP, two irrigation levels and M_3 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 (4,830 and 4,393 kg ha^{-1}) as compared to ZT and CT during both the years. The grain yield was significantly higher with two irrigations levels (4,877 and 4,457 kg ha^{-1}) as compared to one irrigation during both the years. Treatment M_3 (4,837 and 4,415 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 48.22 qha^{-1} during 2020-21 [1]. 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 [2]. 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 [3]. 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 [4].

Wheat is highly sensitive to water stress during the 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. [5] reported that the application of two irrigations at tillering and flowering stage (I_2) resulted in significant increase in Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Leaf Area Index (LAI) than no irrigation (I_0) and one irrigation (I_1) 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 [6].

Mulches enhanced soil water status and improved growth and yield, which subsequently reducing runoff and evaporation losses. Angbabu et al. [7] 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, 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.

2. MATERIALS AND METHODS

The field experiments were conducted at the Research Farm of Wheat and Barley Section, Department of Genetic and Plant Breeding, 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) as main plot and two irrigation levels *i.e.* I_1- one irrigation applied at Crown Root Initiation (CRI) and I_2- two irrigation applied at CRI and booting stages as sub-main plot treatments and four moisture conservation practices *i.e.* M_0 - no mulch, M_1- mulch (pearl millet straw @ 4 tonnes ha^{-1}), M_2 - antitranspirant (kaolin @ 6% w/v) and M_3- 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 P_2O_5 and 40 kg K_2O 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 [8].

3. 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 I_2 treatment (79.64 and 77.89 days) as compared to I_1 (78.81 and 75.64 days) during 2019-20 and 2020-21, respectively. More days were taken for heading by the crop in I_2 treatment (90.33 and 88.08 days) which were significantly higher than I_1 (88.83 and 86.11 days) during 2019-20 and 2020-21, respectively. As well as significantly more days were taken by the crop in I_2 treatment (138.86 and 137.42 days) to attain the physiological stage as compared to days taken in I_1 (136.83 and 135.14 days) 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 [9-12]. Under higher levels of irrigation, the longer reproductive phase of crop growth and longer crop duration has been also reported by Kumar et al. [18].

Among the moisture conservation practices, data indicate that treatments M_3 (80.24 and 79.06 days) and M_1 (79.33 and 76.89 days) significantly took more days for the booting stage as compared to M_2 (78.91 and 76.61 days) and M_0 (78.41 and 74.50 days) during 2019-20 and 2020-21, respectively. Also, among the moisture conservation treatment, M_3 (91.00 and 88.39 days) and M_1 (90.00 and 87.44 days) significantly took more days for the heading stage than M_2 (89.56 and 86.89 days) and M_0 (87.78 and 85.67 days) during 2019-20 and 2020-21, respectively. As well as, M_3 (140.39 and 138.72 days) and M_1 (138.33 and 136.94 days) significantly took more days to attain the physiological maturity stage than M_2 (137.33 and 135.72 days) and M_0 (135.33 and 133.72 days) during both the years, respectively. Whereas, M_0 (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 2 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 (4.29 and 4.04 g dm^{-2} day^{-1}) at 61 to 90 days of crop growth, which was significantly higher than ZT (4.21 and 3.96 g dm^{-2} day^{-1}) but it was statically at par with CT (4.25 and 3.97 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 to harvest. At 91-120 DAS, maximum CGR was recorded in the treatment when two irrigation were applied to the crop (2.46 and 2.00 g dm^{-2} day^{-1}) which was significantly higher over with one irrigation (2.26 and 1.94 g dm^{-2} day^{-1}) during 2019-20 and 2020-21, respectively. Similar trend was also noticed at 120 DAS to harvest stage during both the years. These results are in conformity with the findings of Vishuddha et al. [13] and Kumar et al. [14] 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 (4.31 and 4.06 g dm^{-2} day^{-1}) over all other treatments, *i.e.* M_0 (4.19 and 3.91 g dm^{-2} day^{-1}), M_2 (4.25 and 3.99 g dm^{-2} day^{-1}) and M_1 (4.26 and 4.00 g dm^{-2} day^{-1}) during 2019-20 and 2020-21, respectively. Similar trends were also recorded at 91-120 and 121 DAS to harvesting stage. Brahma et al. [15] obtained similar results and reported that kaolin contributed to enhanced growth indices. Wairagade et al. [16] 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 3. The data revealed that RGR attained maximum value between 31-60 and 61-90 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 (1.42 and 1.38 g/g/day) which was significantly higher than ZT (1.40 and 1.35 g/g/day) but statically at par with CT (1.41 and 1.36 g/g/day) during 2019-20 and 2020-21, respectively. Singh [17] 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) (0.76 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. [13] and Kumar et al. [14] 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 RGR (1.44 and 1.38 g/g/day) over all other treatments *i.e.* M_0 (1.38 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. [18] also reported that among moisture stress management practices, SH + mycorrhizae + KCl spray + kaolin spray recorded significantly highest growth indices, viz. LAI, CGR and RGR over no-management treatment. Brahma et al. [15] also reported that kaolin contributed to enhanced growth indices. Wairagade et al. [16] 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 are presented in Table 1. Bed planting (BP) produced significantly higher grain yield (4,830 and 4,393 kg ha^{-1}) over ZT (4,647 and 4,221 kg ha^{-1}) but statistically at par with CT (4,781 and 4,346 kg ha^{-1}) during 2019-20 and 2020-21, respectively. Whereas, lowest grain yield of 4,647 kg ha^{-1} during 2019-20 and 4,221 kg ha^{-1} during 2020-21 was recorded in ZT. Similar trends have been observed by Singha et al. [19], Kumar et al. [10], and Singh et al. [20]. 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. [21].

Grain yield was significantly influenced by different levels of irrigations. The higher grain yield of wheat (4,877 and 4,457 kg ha^{-1}) was obtained in I_2 treatment (two irrigation) which was significantly higher than I_1 treatment (4,629 and 4,183 kg ha^{-1}) during 2019-20 and 2020-21, respectively. The results are in close conformity with the results reported by Singh and Katiyar [5], Sepat et al. [22], Singh et al., [19]; Kaur et al. [23] also noticed that the higher grain yield with higher level of irrigations.

Among moisture conservation practices, the highest grain yield (4,837 and 4,415 kg ha^{-1}) was produced in the treatment when mulch and antitranspirant were applied to the crop (M_3) which was significantly higher over M_0 (4,612 and 4,186 kg ha^{-1}) but statistically at par with M_1 (4,794 and 4,356 kg ha^{-1}) and M_2 (4,768 and 4,323 kg ha^{-1}) during 2019-20 and 2020-21, respectively. Al-Amin et al. [24] 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 [25-27].

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 Yield (kg ha^{-1})	
	Emergence		Booting		Heading		Physiological Maturity			
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Crop Establishment Methods										
CT	6.35	7.76	79.71	77.29	90.13	87.92	138.63	137.08	4,781	4,346
ZT	6.24	6.99	78.63	76.00	89.00	86.08	136.50	135.00	4,647	4,221
BP	6.25	7.53	79.33	77.00	89.63	87.29	138.42	136.75	4,830	4,393
SEm±	0.10	0.14	0.30	0.84	0.49	0.65	0.70	0.77	45	44
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	142	138
Irrigation Schedules										
I_1	6.27	7.41	78.81	75.64	88.83	86.11	136.83	135.14	4,629	4,183
I_2	6.29	7.45	79.64	77.89	90.33	88.08	138.86	137.42	4,877	4,457
SEm±	0.05	0.09	0.21	0.69	0.40	0.53	0.57	0.63	37	36
CD at 5 %	NS	Ns	0.73	2.17	1.25	1.67	1.81	1.98	116	113
Moisture Conservation Practices										
M_0	6.00	7.17	78.41	74.50	87.78	85.67	135.33	133.72	4,612	4,186
M_1	6.50	7.41	79.33	76.89	90.00	87.44	138.33	136.94	4,794	4,356
M_2	6.02	7.32	78.91	76.61	89.56	86.89	137.33	135.72	4,768	4,323
M_3	6.19	7.02	80.24	79.06	91.00	88.39	140.39	138.72	4,837	4,415
SEm±	0.10	0.13	0.44	0.66	0.24	0.27	0.13	015	48	41
CD at 5 %	NS	NS	1.27	1.88	0.70	0.77	0.39	0.44	137	117

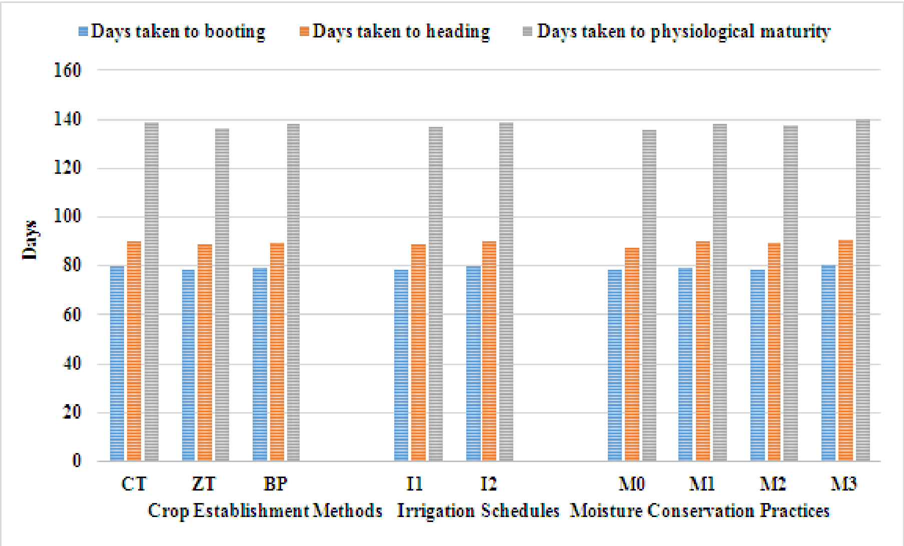

Fig. 1. Phenology of wheat crop as influenced by crop establishment methods, irrigation schedules and moisture conservation practices in wheat crop during 2019-20

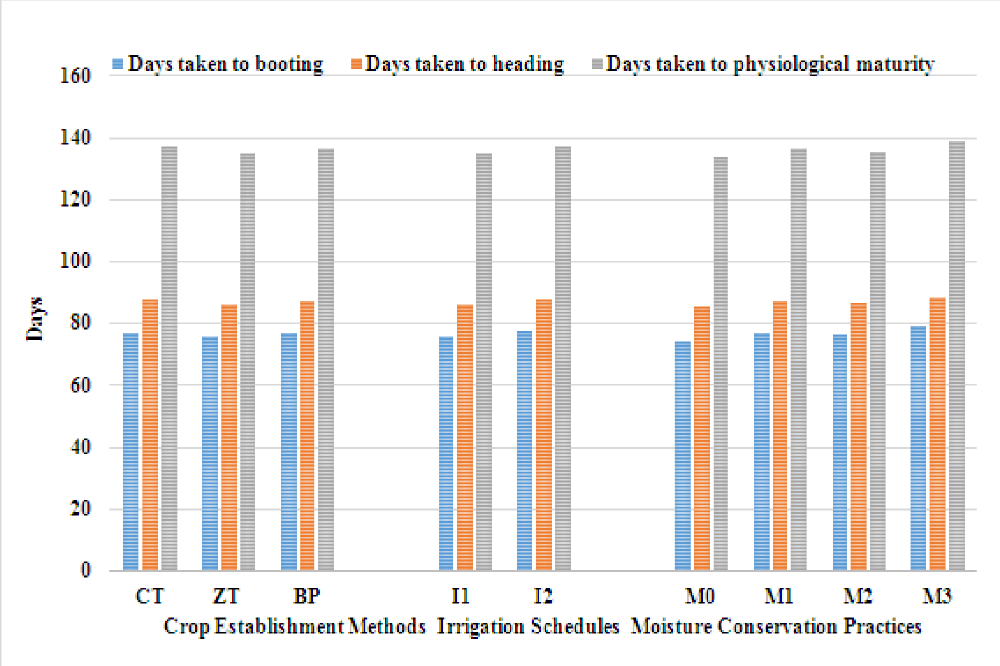

Fig. 2. Phenology of wheat crop as influenced by crop establishment methods, irrigation schedules and moisture conservation practices in wheat crop during 2020-21

Table 2. Effect of different crop establishment methods and moisture conservation practices on Crop Growth Rate (CGR) ($g/m^2/day$) at different stages of wheat under limited irrigated conditions

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

Table 3. Effect of different crop establishment methods and moisture conservation practices on Relative Growth Rate (RGR) (g/g/day) at different stages of wheat under limited 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

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 (I_0); One irrigation (I_1); Critical Difference (CD); Per Cent (%); Seed Hardening (SH); Million per Tonnes (m. t); Standard Error of Mean (SEm); et allii; (co-authors) (et al.); Id east (that is) (i.e.)

4. 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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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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