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

The field experiment was conducted at the Research Farm of CCS Haryana Agricultural University, Hisar during the *Rabi* seasons of 2019-20 and 2020-21. 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.* I_1-one irrigation applied at crown root initiation stage (I_1) and I_2-two irrigation applied at CRI and booting stagess as 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 treatment, were tested 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. However, among the irrigation levels, maximum days taken for booting (79.64 and 7789), heading (90.33 and 88.08) and physiological maturity (138.86 and 137.42) stages under two irrigation (I_2) and minimum *i.e.* 78.81 and 75.64; 88.83 and 86.11; 136.83 and 135.14 were taken in one irrigation during 2019-20 and 2020-21, respectively. Among moisture conservation practices significantly higher days taken for booting (80.24 and 79.06), heading (91.00 and 88.39) and physiological maturity (140.39 and 138.72) stages in M_3 treatment over M_0 78.41 and 74.50; 87.78 and 85.67; 135.33 and 133.72 but 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 was recorded in BP 4873 and 4423; two irrigation levels 4,880 and 4,465 and M_3 4,879 and 4,468 which was significantly higher 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

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Introduction

Wheat is one of the most important cereal crop 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 m ha, 108.75 m t and 34.24 q ha^{-1}, respectively during 2020-21. In Haryana, it is grown over an area of 2.52 m ha with a production of 12.15 m t and productivity of 48.22 q ha^{-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 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 (I_2) resulted in significant increase in CGR (g^{-1} m^{-2}-day^{-1}), RGR (g^{-1} g^{-1} day^{-1}) and 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, 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 @ 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

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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 *i.e.* conventional tillage (CT), zero tillage (ZT) and bed planting (BP) and two irrigation levels *i.e.* one irrigation applied at crown root initiation (CRI) (I_1) and two irrigation applied at CRI and booting stages (I_2) as main plot treatment and four moisture conservation practices *i.e.* no mulch (M_0), mulch (pearl millet straw @ 4 tonnes ha^{-1}) (M_1), antitranspirant (kaolin @ 6% w/v) (M_2) and mulch (pearl millet straw @ 4 tonnes ha^{-1}) + antitranspirant (kaolin @ 6% w/v) as sub-plots treatment, were tested in a split split-plot design with three replications. 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 (1959).

Results and Discussion

The data on days taken to the emergence, days taken to booting, days taken to heading and days taken to physiological maturity stages of wheat as influenced by crop establishment methods, irrigation schedules and moisture conservation practices 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 78.61) as compared to I_1 (78.81 and 75.64) 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) which were significantly higher than I_1

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(88.83 and 86.11) 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) to attain the physiological stage as compared to days taken in I_1 (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 Mashiqa, 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 M_3 (80.24 and 79.06) and M_1 (79.33 and 76.89) significantly took more days for the booting stage as compared to M_2 (78.91 and 76.61days) 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) and M_1 (90.00 and 87.44) 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) and M_1 (138.33 and 136.94) 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 1 showed that there was no significant difference in CGR due to crop establishment methods at 0-30 and 31-60 DAS during both the years. At 61-90 DAS, maximum CGR was recorded with BP (4.30 and 4.05 g dm^{-2} day^{-1}) which was significantly greater than ZT (4.22 and 3.96 g dm^{-2} day^{-1}) but it was 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 I_2 (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 there was no significant differences in CGR at 0-30 DAS during both the years. 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*

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Comment [MF19]: Insert a come please *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 pertaining to the RGR at various stages was analyzed statistically and the data as influenced by different treatments 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. Among methods of crop establishment, at 61-90 DAS stage, maximum RGR was recorded with BP (1.44 and 1.38 g/g/day) which was significantly higher than ZT (1.42 and 1.36 g/g/day) but was at par with CT (1.43 and 1.37 g/g/day) during 2019-20 and 2020-21, respectively. Similar trend was also reported by Singh (2017). 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. Among moisture stress management practices, SH + mycorrhizae + KCl spray + kaolin spray recorded significantly highest growth indices, viz. LAI, CGR and RCG over on-management treatment (Patil *et al*., 2014). 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. Bed planting (BP) produced significantly higher grain yield of wheat (4,873 and 4,423Kg ha^{-1}) over ZT (4,645 and 4,220 Kg ha^{-1}) but statistically at par with CT (4,751 and 4,330 Kg ha^{-1}) during 2019-20 and 2020-21, respectively. Whereas, lower grain yield of 4,645 during 2019-20 and 4,220 Kg ha^{-1} during 2020-21was recorded in ZT. Similar trends have been observed by Singha *et al*. (2018), Kumar *et al.* (2018) and Singh *et al*. (2019). Sagar *et al*. (2017) reported higher grain in bed planting than another crop establishment. Higher grain yield with bed planting of wheat has been also reported by Thind *et al. (*2010).

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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 I_2 treatment (two irrigation) which was significantly higher than I_1 treatment (4,633 and 4,184 Kg ha^{-1}) during 2019-20 and 2020-21, respectively. Similar results were reported by Singh and Katiyar, 2014; Sepat *et al.* 2015 Singh *et al.*, 2018; Kumar *et al*., 2018. Also, Kaur *et al*. (2018) noticed that the higher yield is due to the strong effect of irrigation frequency and mulch on grain yield. As well as that moisture conservation practices significantly affected the grain yield of wheat. The maximum grain yield (4,879 and 4,468 Kg ha^{-1}) was produced in the treatments when mulch and antitranspirant were applied to the crop (M_3) which was significantly higher over M_0 (4,589 and 4,154 Kg ha^{-1}) but statistically at par with M_1 (4,785 and 4,341 Kg ha^{-1}) and M_2 (4,772 and 4,333 Kg ha^{-1}) during both the years of investigation respectively. Similar findings were also been described by (Ahmed *et al.*, 2009; Sarwar *et al*., 2013; Patil *et al*., 2014; Singh *et al*., 2018) Also, Al-Amin *et al.* (2017) noticed that the higher grain yield in straw mulch @ 6 t ha^{-1} while the lowest grain yield was recorded in control. This may occur due to the different environmental factors and cultural management practices.

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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	4,751	4,330
ZT	6.24	6.99	78.63	76.00	89.00	86.08	136.50	135.00	4,645	4,220
BP	6.25	7.53	79.33	77.00	89.63	87.29	138.42	136.75	4,873	4,423
SEm±	0.10	0.14	0.30	0.84	0.49	0.65	0.70	0.77	46	49
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	145	154
Irrigation schedules										
I_1	6.27	7.41	78.81	75.64	88.83	86.11	136.83	135.14	4,633	4,184
I_2	6.29	7.45	79.64	77.89	90.33	88.08	138.86	137.42	4,880	4,465
SEm±	0.05	0.09	0.21	0.69	0.40	0.53	0.57	0.63	37.51	40
CD at 5 %	NS	Ns	0.73	2.17	1.25	1.67	1.81	1.98	118	126
Moisture Conservation Practices										
M_0	6.00	7.17	78.41	74.50	87.78	85.67	135.33	133.72	4,589	4,154
M_1	6.50	7.41	79.33	76.89	90.00	87.44	138.33	136.94	4,785	4,341
M_2	6.02	7.32	78.91	76.61	89.56	86.89	137.33	135.72	4,772	4,333
M_3	6.19	7.02	80.24	79.06	91.00	88.39	140.39	138.72	4,879	4,468
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	136	119

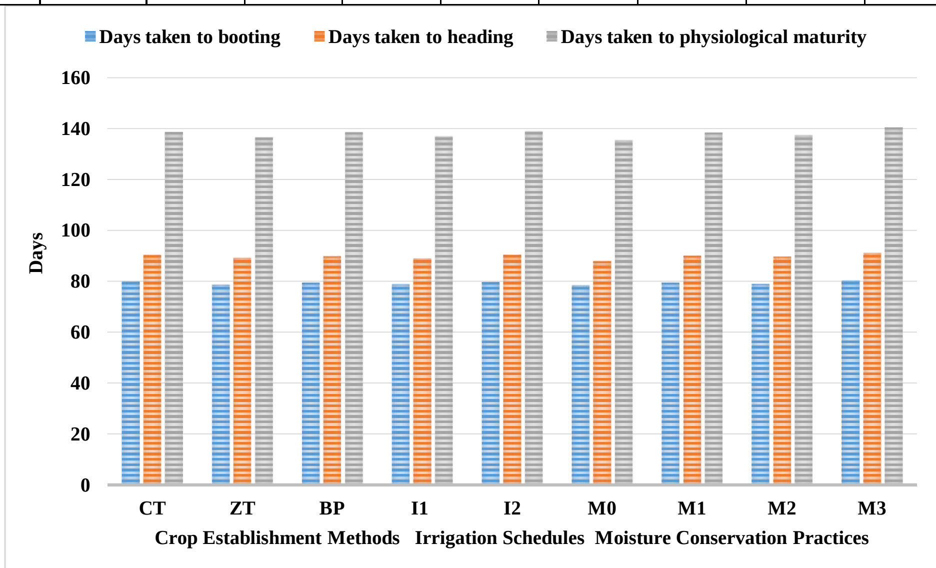

Fig. 1. Phenology of wheat crop as influenced by crop establishment methods, irrigation schedules and moisture conservation practices in wheat crop during 2019-20

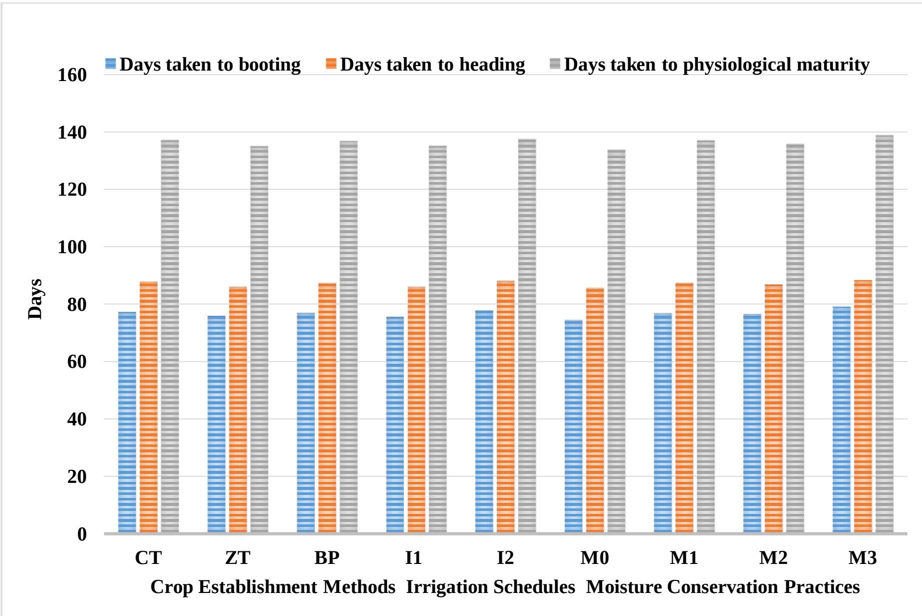

Fig. 2. Phenology of wheat crop as influenced by crop establishment methods, irrigation schedules and moisture conservation practices in wheat crop during 2020-21

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

Conclusion

BP sowing was found suitable in terms of phenology, growth indices and yield among crop establishment methods and wheat crop perform better with the application of two irrigations as well as the application of kaolin as anti-transpiration under limited irrigation conditions.

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