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Effect of different environments and sowing methods on wheat productivity in *Tawa* command area of Madhya Pradesh

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Abstract
A field experiment was conducted during the winter season of 2019-20 and 2020-21 to study the effect on wheat production and productivity under four thermal environments (E_1:15th November, E_2:30th November, E_3:15th December, E_4:30 December) and three sowing methods (M_1: Broadcast, M_2: Line sowing and M_3: Bed planting) were evaluated in a three replication with Split Plot Design. (E_1: thermal environment) recorded significantly plant height (92.78 and 91.44 cm) dry matter accumulation (1270 and 1253 g m^{-2}), number of tillers (429 and 420) and leaf area index (4.71 and 4.75) number of tillers (436 and 422 m^{-2}) spike length (9.78 and 9.5 cm), grains spike^{-1} (59.33 and 53.89) and test weight (48.89 and 47.78 g) grain yield maximum (5262 and 4941 kg ha^{-1}) straw yield (7441 and 7594 kg ha^{-1}) harvest index (41.36 and 39.34). The crop sown on E_1 and method M_3 was maximum production and best treatment combination. The maximum number of tillers (430 and 421), spike length (9.54 and 9.13 cm), grain spike^{-1}(52.25 and 49.33) and test weight (43.75 and 42.25 g), grain yield (5050 and 4761 kg ha^{-1}) straw yield (7557 and 7655 kg ha^{-1}) harvest index (39.90 and 38.16) in M_3. The method M_3 was found significantly superior over the rest of methods.

Keywords: dry matter accumulation, leaf area index, sowing environments, sowing methods temperature, wheat

Introduction
Wheat (*Triticum aestivum* L.) is the world's largest cultivated grain crop, which belongs to the family Poaceae and genus *Triticum.* Its highly productive crop with high adaptability to different agro-climatic and soil conditions, therefore, occupies more acreage. Wheat cultivation is also the symbol of the green revolution, self-sufficiency of food, and sustained production (Alam, 2013) [2]. India is one of the major wheat producers after China and contributes more than 30% to the globe. In the central zone, the optimum time for sowing is the second fortnight of November. The optimum temperature regime during the growing season of wheat crop range between 20-22 ^{0}C at sowing time, 16-22 ^{0}C at tillering stage to grain filling stage, and the slow temperature rises to 40 ^{0}C at harvesting time (Sharma *et al.*, 2000). A sudden increase in temperature for 4-5 days at any stage of growth can adversely affect the wheat yield (Spiertz *et al*., 2006). The increase in temperature by 1-3 ^{0}C is likely to advance the optimum sowing time by 5-8 days per degree rise in temperature. Wheat is generally planted by line sowing method by most of the farmers of Madhya Pradesh and broadcasting is an old conventional method of sowing for wheat. The bed planting system of wheat sowing is relatively a new technology in India. This sowing system facilitates mechanical weed control, improves water-use efficiency, and reduces crop lodging and seeding rate. It has been reported that bed planting of wheat increases the yield by 10%, reduces the cost of production to about 20-30%, and irrigation water requirement up to 35% (Yadav *et al*., 2002b). Wheat is being photo-thermosensitive crop, selected of suitable wheat variety for different sowing time with suitable sowing methods and other agronomic management will further get prime importance. Temperature influences the crop phenology and yield of the crop (Bishnoi *et al.*, 1995). Plants have an obvious temperature requirement before they attain certain phenological stages. Therefore, experimentation was conducted to determine the heat unit requirement for wheat under different thermal environments and sowing methods under the *Tawa* command area, Madhya Pradesh.

Materials and Methods

The field experiment was carried out at Zonal Agricultural Research Station, Powarkheda, Hoshangabad (M.P.), located in the Central Zone of India has a tropical and sub-tropical climate. This Centre is situated on the bank of the holy river Narmada at 77.42^0 N Latitude, 22.40^0 E Longitude and 299 m above mean sea level Altitude. The area was rich in deep black vertisol soil, having a pH of 7. The experiment was laid out in a split-plot design with three replications and four different sowing environments as main plot (15^{th} November, 30^{th} November, 15^{th} December, 30 December) and three sowing methods (Broadcast, Line sowing, and Bed planting) as subplots. The crop was grown with all recommended packages of practices of the region. The crop was sown at recommended seed rate *i.e.* 125 kg ha^{-1} in broadcasting method and @100 kg ha^{-1} in line sowing and bed planting methods, and treated with Vitavax @ 2 gm kg^{-1} seed. Sowing was done manually and thereafter furrows were covered. The bed planting method is leveling of field, a pre-condition for the success of this technology. The field preparation, bed formation by bed planter, placement of fertilizer, and sowing of seed was done manually. Furrows were used for irrigation as well as for drainage of excess water if there is heavy rain during the crop season. Generally, 3 rows of wheat can be planted on the top of each bed. The bed is 67 cm (center-to-center) wide beds were made; the height of beds was 15 cm. After preparing the layout and marking the individual plots, the furrows were manually opened with kudali for sowing at the spacing of 22.5 cm. during both seasons. The basal dose of fertilizers in the required quantity was applied as per treatments in the furrows and mixed in the soil. Sowing was done manually and thereafter furrows were covered.

The weekly maximum temperature varied from 24.5 ^{0}C to 44.3 ^{0}C in the crop season of 2019-2020 while minimum temperature varied from 4.0 ^{0}C to 22.0 ^{0}C. The maximum temperature was varied from 25.5 ^{0}C to 40.5 ^{0}C during the year 2020-21, while the minimum temperature varied from 5.5 ^{0}C to 22.5 ^{0}C. The maximum temperature was recorded higher during the crop season of 2019-20 than 2020-21. Overall, it was almost similar during both the years of the crop season. Relative humidity in the morning was similar in the first year and second year 96 % and lower 46 % and 49 % while the evening RH was higher during first year 59% lower 15 % and second year 57 % and lower 9% of the crop season. The rainfall was 27 mm and 11.5 mm received in 8 and 7 rainy days during the first and second year respectively. The crop was exposed to a total sunshine duration of 182.6 and 197.8 hours during the total life span of the crop in the first and second years respectively. All the weather conditions were favourable for the wheat crop.

Leaf area index

Leaf area was measured with leaf area meter (CI-203 model, CID Bio-Science, WA, USA). The green plants in 25 cm row length were uprooted and leaves were separated and their area was measured. The following equation was used for the calculation of the leaf area index (LAI) (Watson, 1952).

$$LAI = \frac{\text{Total green leaf area of the plants (cm}^2)}{\text{Total ground area (cm}^2)}$$

Harvest Index

It refers to the ratio of economic yield (seed yield) in the biological yields (seed + straw) and it is expressed under a particular treatment in percentage. It was worked for each plot by using the following formula (Nichiporvich, 1967),

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (seed yield kg/ha)}}{\text{Biological yield (seed + straw yields kg/ha)}} \times 100$$

Results and Discussion

Result of growth attributes in the revealed that the sundry growth parameters (Table 1 & 2) decremented significantly superior over rest treatments with each delay in sowing environments. Timely sowing environment (E_1:15th November) recorded significantly higher plant height (92.78 and 91.44 cm) dry matter accumulation (1270 and 1253 g m^{-2}), number of tillers (429 and 420 m^{-2}) and leaf area index (4.71 and 4.75), and (bed planting) recorded significantly plant height (91 and 90.42 cm) dry matter accumulation (1261 and 1242 g m^{-2}), number of tillers (430 and 421 m^{-2}) and leaf area index (5.37 and 5.35). Growth attributes were decremented with deferral in sowing time because of less propitious weather conditions and shorter crop growing periods that resulted in poor net photosynthesis as compared to optimum sowing dates. Several authors have reported reduction in growth attributes with delay in sowing time from the optimum (Jat *et al*., 2013; Tomar *et al*., 2014 and Mumtaz *et al*., 2015) [17, 24]. During the later stages plant height, total tillers, and dry matter accumulation in E_2, E_3, and E_4 were statistically paramount with each other. The late sown crop was subjected to low temperature during the early growth period, the longer vegetative phase led to the engendered of growth attributes. Findings were recorded by Ghadekar *et al*., (1992) [11]. DMA decremented with deferral in sowing time because of less propitious weather conditions and shorter crop growing period, minimized plant height and, LAI. Alam *et al*., 2013 [2]; Kumar *et al*., 2013 and Deshmukh *et al*., 2015 [7] additionally reported that DMA was higher in the early sown crop because of propitious cool climate accessible for a longer period as compared to late sown crop. Further, since this period coincide with a conducive period for crop growth truncating death of tiller and senescence of leaf, thus accumulating.

Interaction effect

Plant height: The interaction effects between different environment and sowing methods on plant height was minimum in E_4 with M_1 found significantly superior over rest environment combination. The higher plant height was found E_1 with M_3 significantly superior over rest environment combination. Similar results found by Mukherjee (2012) [23] and Baloch *et al.* (2010)

Dry weight: The interaction effects between sowing environment and methods on minimum plant dry weight recorded in E_4 with M_1 found significantly superior over rest environment combination. The higher plant weight was found E_1 with M_3 significantly superior over rest environment combination. These finding are in line with Singh (2016). Plant dry weight was influenced by different sowing methods which observed and minimum in M_1 However, maximum in M_3 and found significantly superior over M_2 & M_1. The results are in line with those obtained by Gupta *et al.* (2017) [13] and Kumar *et al*. (2017).

Leaf area index: The interaction effects between sowing environment and methods on leaf area index was minimum in E_4 with M_1 found significantly lower rest of the treatment combination. The higher leaf area index in E_1 with M_3 was found significantly superior over rest of sowing environments and it was found at par E_3. Similar result was reported by Suleiman *et al.* (2014). Leaf area index was influenced by different sowing methods which was minimum (3.03) in M_1 However, maximum (4.90) was recorded in M_3 and found significantly superior over M_2 and M_1. Similar finding were observed by Chouhan *et al.* (2017) and Gupta *et al.* (2017) [13].

Yield and yield attributes

The data depicted in Table 1 & 2 revealed significantly higher yield attributes viz. number of tillers (429 and 420) m^{-2}) spike length (9.78 and 9.5 cm), grains $spike^{-1}$ (59.33 and 53.89), and test weight (44.44 and 43.78 g) were recorded with E1:15th November environment. With each delay in sowing, there was a paramount minimization in the yield attributes. Yield attributes as influenced by different Sowing methods and found as a maximum number of tillers (430 and 421 m^{-2}), spike length (9.54 and 9.13 cm), grain $spike^{-1}$(52.25 and 49.33), and test weight (44.5 and 43.85 g) in M_3. The bed planting method was found significantly superior to the rest method. The minimum yield attributes viz. number of tillers (407 and 393) spike length (7.39 and 7.39 cm), grains $spike^{-1}$ (37 and 33.67), and test weight (43.78 and 42.96 g) in 30th December environment. Yield attributes are minimum in *viz*. number of tillers (404 and 395 m^{-2}), spike length (8.0 and 7.92cm), grain $spike^{-1}$(42.5 and 36.75), and test weight (43.5 and 43.2 g) in the M_1 broadcast method. The total and effective tillers were higher in earlier sowing due to the higher number of total tillers at all the magnification stages together with propitious weather conditions throughout the growing season. Ramesh *et al*., (2005) additionally reported abbreviation in the number of total and effective tillers with deferral in the sowing environment. Significantly higher grains $spike^{-1}$ and spike weight with D_1 as compared to all other sowing dates may be attributed to the unpropitious effect of late sowing on yield attributing characters like grains $spike^{-1}$ and spike weight can be attributed to sharp ascend in temperature accompanied by sultry winds adversely affecting the grain development and resulted in juvenile and shriveled grains in the late sown crop, which was in the milk stage during that period. 15th October sown crop, however, was at an advantage because after having consummated its vegetative magnification satisfactorily, it entered the reproductive phase when grain development and maturity was subjected to a steady ascend in temperature. Kindred findings were corroborated by Angadi and Janawade (2001) [4] and Singh and Pal (2003).

Interaction effect

Effective tillers: The interaction effects between different environments and sowing methods on minimum tillers recorded in E_4 with M_1 was significantly lower treatment combination. The higher number of tillers in E_1 with M_3 was found significantly superior over rest of sowing environments and it was at par of E_2, E_3 and E_4 at harvest during both the years of experiment. Same result was reported by Nizamuddin *et al*. (2014). The finding is in support to those of Chaudhary *et al.* (2016), Abbas *et al.* (2009) [1], Soomro *et al.* (2009).

Length of spike: The interaction effects between different environments and sowing methods on length of spike of wheat was minimum in E_4 with M_1 was found significantly lower treatment combination. The length of spike in E_1 with M_3 was found significantly superior over the rest treatment combination. The results are supported by Baloch *et al*. (2010), reported that early sown crop produced maximum spike length than delayed sown crops.

Number of grains: The interaction effects between sowing environment and methods on number of grains $spike^{-1}$ of wheat was minimum in E_4 with M_1 was found significantly lower of the treatment combination. The number of grains $spike^{-1}$ of wheat in E_1 with M_3 was found significantly superior over rest of the treatment respectively. Methods of sowing also influenced significantly number of grains $spike^{-1}$ of wheat. The result was supported by Baloch *et al.* (2012) reported higher number of gains per spike with earlier sown crop. Among the methods of sowing M_3 showed maximum number of grains $spike^{-1}$ of wheat which was significantly superior over the rest treatment respectively. The results are in inversive with the finding of Carver (2005), Parihar and Singh (1995), Bakht *et al.* (2006).

Grain yield (kg ha^{-1})

Data concern to grain yield (kg ha^{-1}) was recorded at harvest and presented in Table 5 & 6, fig 5. Grain yield was minimum (3689 and 3333 kg ha^{-1}) in E_4 However, maximum (5262 and 4941 kg ha^{-1}) was recorded in E_1 sowing environment that was found significantly superior over rest of the Sowing environment. Reduction of grain yield in E_2, E_3 & E_4 Sowing environments recorded 4.9, 17.6, and 32.5% as compared to E_1 sowing environments respectively. Higher grain yield in 30th November sown crop may be attributed to better plant growth leading to significantly more yield attributes and better partitioning of photosynthates (Kumar *et al*. 2009). Significant increases in grain yield when sowing was delayed beyond 15th November. Delayed sowing hastened the crop phenological development, thereby causing a significant reduction in yield. Singh and Paul (2003); Amrawat *et al*. (2013) and Pandey *et al*. (2010) also reported similar findings. Every reduction in yields in late sown crop might be due to the detrimental effect of higher temperature at heading to milking and milking to dough phases of a crop causing poor grain filling (Jat *et al*. 2013) [17]. Grain yield was influenced by different sowing methods found maximum (5050 and 4761 kg ha^{-1}) inM_3 it was found significantly superior over M_2 (4541 and 4252kg ha^{-1}) and M_1 (4096 and 3767kg ha^{-1}). Reduction of grain yield found in M_2 & M_1 which recorded 10.6 and 20.8% as compared to M_3 respectively. The straw yield was recorded minimum (6901 and 6826 kg ha^{-1}) in E_4 However, maximum yield (7441 and 7594 kg ha^{-1}) was recorded in E_1 sowing environment and found at par with E_2. Reduction of straw yield found in E_2, E_3 & E_4 Sowing environments and recorded 1.7, 5.4, and 8.7% as compared to the E_1 sowing environment respectively. Straw yield influenced by different sowing methods and maximum (7557 and 7655 kg ha^{-1}) in M_3 it was found significantly superior over M_2 (7201 and 7237 kg ha^{-1}) & M_1 (6858 and 6800kg ha^{-1}). Reduction of straw yield in M_2 & M_1 recorded 5.0 and 10.2% as compared to M_3 respectively. Biological yield recorded minimum (10590 and 10159 kg ha^{-1}) in E_4 However, maximum (12703 and 12535 kg ha^{-1}) was recorded in E_1 sowing environment and was found at par to E_2 reduction of biological yield in E_2, E_3 & E_4 sowing environments recorded 3.2, 10.3 and 17.7% as compared to E_1 sowing environment respectively. Biological yield influenced by different sowing method and as recorded maximum (12607 and 12416 kg ha^{-1})

under M_3 it was found significantly superior over M_2 (11742 and 11489 kg ha^{-1}) & M_1 (10954 and 10567 kg ha^{-1}). Reduction of biological yield in M_2 & M_1 recorded 7.1 and 13.9% as compared to M_3 respectively. Harvest index had seen minimum (34.78 and 32.75) in E_4 However, found maximum (41.36 and 39.34) in E_1 sowing environment and found significantly superior over the rest treatments E_2. Reduction of harvest index in E_2, E_3 & E_4 sowing environments recorded 2.1, 8.1, and 16.3% as compared to E_1 sowing environment respectively. Harvest index influenced by different sowing methods and found as maximum (39.90 and 38.16) in M_3 it was found significantly superior over M_2 (38.49 and 36.79) & M_1 (37.22 and 35.45). Reduction of harvest index in M_2 & M_1 recorded 3.5 and 6.9% as compared to M_3 respectively. The decline in grain yield with delay in sowing may be due to shortening of the duration of each developmental phase and forced maturity of late sown wheat, reduction in plant height, DMA, LAI, and tiller density. Moreover, the yield attributes like effective tillers, grains ear^{-1}, and 1000-grain weight were reduced under delayed sowing which may be responsible for lesser grain yield. Similar results have been reported by Qasim *et al*., (2008), Gao *et al*., (2014), and Arzian *et al*., (2015). Jakhar *et al.* (2005) reported that plant height was significantly higher in bed planted wheat (92.11 cm) in comparison to conventionally sown crops (83.23 cm). Abbas *et al.* (2009) [1] revealed that the better plant height was noted in drill Sowing with 30 and 22.5 cm rows. However, number of spikelets $spike^{-1}$ and number of grains $spike^{-1}$ were statically similar in broadcasting and drilling at 22.5 cm apart rows. Kaur (2012) revealed that the Photosynthetically Active Radiation (PAR) interception percentage, canopy temperature, leaf area index, and dry matter accumulation were also higher under bed planted crop as compared to flat planted crop. Gupta *et al.* (2017) [13] observed that the effects were noted under drill sowing at 18 and 20 cm and bed planting with 3 rows which were better in terms of growth and yield. Dry matter accumulation, number of tillers m^{-2}, leaf area index, and light interception were significantly higher with drill sowing at 18 cm row spacing. However, spike length was highest with bed planting (2 rows). The highest grain yield (50.94 q ha^{-1}) was obtained with 18 cm row spacing.

Interaction effect

Grain yield: The interaction effects between sowing environment and methods on grain yield of wheat was minimum in E_4 with M_1 found significantly lower rest of the treatment combination. The grain yield of wheat E_1 with M_3 was found significantly superior over the rest treatments combination. The results are in the line to those of Pirzada *et al.* (2018), Gupta *et al.* (2017) [13], Razaq *et al.* (2016) and Kumar *et al*. (2017).

Straw yield: The interaction effects between sowing environment and methods on straw yield of wheat achieved minimum in E_4 with M_1 found significantly lower rest of the treatment combination. The straw yield of wheat E_1 with M_3 was found significantly superior over the rest treatments combination, and it was found at par E_2. Baloch *et al.* (2010) reported higher straw yield with early sown crop.

Harvest Index: The interaction effects between sowing environment and methods on harvest index of wheat was minimum in E_4 with M_1 found significantly lower rest of the treatment combination. The grain yield of wheat E_1 with M_3 was found significantly superior over the rest treatments combination. Different sowing methods influenced harvest index significantly. Similar results were obtained by Kaur *et al.* (2015), Razaq *et al.* (2016), Tadesse *et al.* (2017), El-Temsah (2017) and Pirzada (2018). Ahuja *et al.* (1996) and Raj *et al*. (1992**)** reported positive correlation of harvest index with grain yield.

Table 1: Growth and Yield attributes of wheat as influenced by different Sowing environments and methods

Treatments	Plant height (cm)			dry weight (gm^{-2})			Leaf area index			Number of tillers m^{-2}			Length of spike (cm)			number of grains spike^{-1}			Test weight (g)			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest Index		
	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean
Sowing environments																														
E_1:15th Nov.	92.8	91.4	92.1	1270	1253	1262	4.71	4.75	4.7	429	420	425	9.78	9.5	9.6	53.3	50.6	51.9	44.4	43.8	44.1	5262	4941	4941	7441	7594	7518	41.4	39.3	40.4
E_2 :30th Nov.	89.8	88.1	88.9	1233	1215	1224	4.38	4.42	4.4	422	411	417	9.06	9	9	50.2	44.6	47.4	44.2	43.7	44.0	4963	4696	4696	7365	7400	7383	40.2	38.8	39.5
E_3:15th Dec.	87.1	86.8	86.9	1145	1117	1131	4.06	4.03	4	413	402	407	8.67	8.06	8.4	42.4	39.2	40.8	44.1	43.6	43.8	4336	4069	4069	7114	7103	7108	37.8	36.4	37.1
E_4: 30th Dec.	85.2	84.3	84.8	1059	1016	1037	3.82	3.87	3.8	407	393	400	7.39	7.39	7.4	37.0	35.0	36.0	43.8	43.0	43.4	3689	3333	3333	6901	6826	6864	34.8	32.8	33.8
Mean	89	88	88	1177	1150	1164	4	4	4	418	407	412	9	8	9	46	42	44	44	44	44	4562	4260	4260	7205	7231	7218	38.5	36.8	37.7
SEm ±	0.65	0.81	0.37	12.98	13.2	12.6	0.05	0.01	0	3.69	2.68	2.35	0.09	0.08	0.1	2.59	1.59	1.75	0.1	0.13	0.1	36.37	35.2	35.2	95.52	98.92	95.57	0.13	0.11	0.12
CD at 5%	2.26	2.8	1.28	44.91	45.7	43.5	0.16	0.03	0.1	12.8	9.27	8.12	0.32	0.27	0.2	8.98	5.51	6.05	0.33	0.43	0.35	125.86	121.8	121.8	330.5	342.3	330.7	0.44	0.38	0.41
Sowing methods																														
M_1: Broadcast	85.9	84.1	85.0	1095	1057	1076	3.37	3.42	3.4	404	395	399	8	7.9	8.0	40.7	37.9	39.3	43.5	43.2	43.4	4096	3767	3767	6858	6800	6829	37.2	35.5	36.3
M_2: Line sowing	89.3	88.5	88.9	1174	1153	1164	4.03	4.02	4	420	404	412	8.63	8.4	8.5	45.2	41.9	43.5	44.4	43.5	43.9	4541	4252	4252	7201	7237	7219	38.5	36.8	37.6
M_3: Bed planting	91.0	90.4	90.7	1261	1242	1251	5.33	5.37	5.4	430	421	425	9.54	9.1	9.3	51.4	47.2	49.3	44.5	43.9	44.2	5050	4761	4761	7557	7655	7606	39.9	38.2	39.0
Mean	88.7	87.7	88.2	1177	1151	1164	4	4	4	418	407	412	9	8.0	9.0	46.0	42.0	44.0	44.0	44.0	44.0	4562	4260	4260	7205	7231	7218	38.5	36.8	37.7
SEm ±	0.21	0.4	0.22	4.39	6.5	4.66	0.07	0.05	0.1	1.78	2.72	1.89	0.08	0.1	0.1	0.85	1.03	0.74	0.16	0.16	0.12	11.21	23.52	23.52	39.18	38.96	34.83	0.12	0.1	0.11
CD at 5%	0.63	1.21	0.66	13.15	19.5	14	0.21	0.16	0.2	5.35	8.16	5.65	0.25	0.3	0.2	2.56	3.09	2.23	0.49	0.47	0.37	33.62	70.52	70.52	117.5	116.8	104.4	0.37	0.29	0.33

Table 2: Interaction effect of growth and yield attributes of wheat as influenced by different Sowing environments and methods (mean of two years)

Treatments	Plant height at harvest(cm)					dry weight (gm^{-2})					Leaf area index					Effective tillers m^{-2}					Length of spike (cm)				
	E_1:15th Nov.	E_2: 30th Nov.	E_3 :15th Dec.	E_4: 30th Dec.	Mean	E_1:15th Nov.	E_2: 30th Nov.	E_3 :15th Dec.	E_4: 30th Dec.	Mean	E_1:15th Nov.	E_2: 30th Nov.	E_3 :15th Dec.	E_4: 30th Dec.	Mean	E_1:15th Nov.	E_2: 30th Nov.	E_3 :15th Dec.	E_4: 30th Dec.	Mean	E_1:15th Nov.	E_2: 30th Nov.	E_3 :15th Dec.	E_4: 30th Dec.	Mean
M_1: Broadcast	90.6	87.7	84.5	79.5	85.6	1161	1140	1049	954	1076	3.3	3.1	3.0	2.7	3.03	415	412	389	382	399	9.25	8.5	7.6	6.5	8.0
M_2: Line sowing	93.4	90.5	87.8	86.4	89.5	1279	1239	1115	1021	1164	4.1	4.0	3.4	3.2	3.66	421	412	416	398	412	9.33	9.0	8.3	7.5	8.5
M_3: Bed Planting	93.9	91.8	90.8	88.4	91.2	1346	1293	1229	1137	1251	5.7	4.9	4.6	4.5	4.9	438	426	417	420	425	10.3	9.6	9.3	8.2	9.3
Mean	92.6	90.0	87.7	84.8		1262	1224	1131	1037		4.4	4.0	3.7	3.5		425	417	407	400		9.64	9.0	8.4	7.4	
	E	M	E x M	M x E		E	M	E x M	M x E		E	M	E x M	M x E		E	M	E x M	M x E		E	M	E x M	M x E	
SEm ±	0.4	0.21	0.41	0.5		12.56	4.66	9.32	14.18		0.03	0.06	0.11	0.09		2.35	1.89	3.77	3.55		0.05	0.06	0.13	0.1	
CD at 5%	1.38	0.62	1.24	1.11		43.45	13.97	27.94	32.63		0.11	0.17	0.34	0.18		8.12	5.65	11.3	7.64		0.17	0.19	0.38	0.21	
	Number of grains spike^{-1}					**Grain yield (kg ha^{-1})**					**Straw yield (kg ha^{-1})**					**Harvest Index**									
Treatments	E_1:15th Nov.	E_2: 30th Nov.	E_3 :15th Dec.	E_4: 30th Dec.	Mean	E_1:15th Nov.	E_2: 30th Nov.	E_3 :15th Dec.	E_4: 30th Dec.	Mean	E_1:15th Nov.	E_2: 30th Nov.	E_3 :15th Dec.	E_4: 30th Dec.	Mean	E_1:15th Nov.	E_2: 30th Nov.	E_3 :15th Dec.	E_4: 30th Dec.	Mean					
M_1: Broadcast	50	42.83	35	30.67	39.63	4311	4222	3585	2948	3767	7084	7047	6772	6413	6829	38.96	38.19	35.44	32.74	36.33					
M_2: Line sowing	53.5	45.5	44.5	33.67	44.29	5007	4667	4044	3289	4252	7647	7506	6976	6748	7219	40.2	39	37.45	33.91	37.64					
M_3: Bed Planting	66.33	54	41.17	41.67	50.79	5504	5200	4578	3763	4761	7822	7595	7578	7429	7606	41.89	41.25	38.33	34.64	39.03					
Mean	56.61	47.44	40.22	35.33		4941	4696	4069	3333		7518	7383	7108	6864		40.35	39.48	37.07	33.77						
	E	M	E x M	M x E		E	M	E x M	M x E		E	M	E x M	M x E		E	M	E x M	M x E						
SEm ±	1.73	0.86	1.73	2.12		35.2	23.52	47.04	48.43		95.57	34.83	69.67	107.52		0.12	0.11	0.22	0.19						
CD at 5%	5.98	2.59	5.17	4.74		121.81	70.52	141.03	105.78		330.71	104.43	208.87	247.79		0.41	0.33	0.65	0.41						

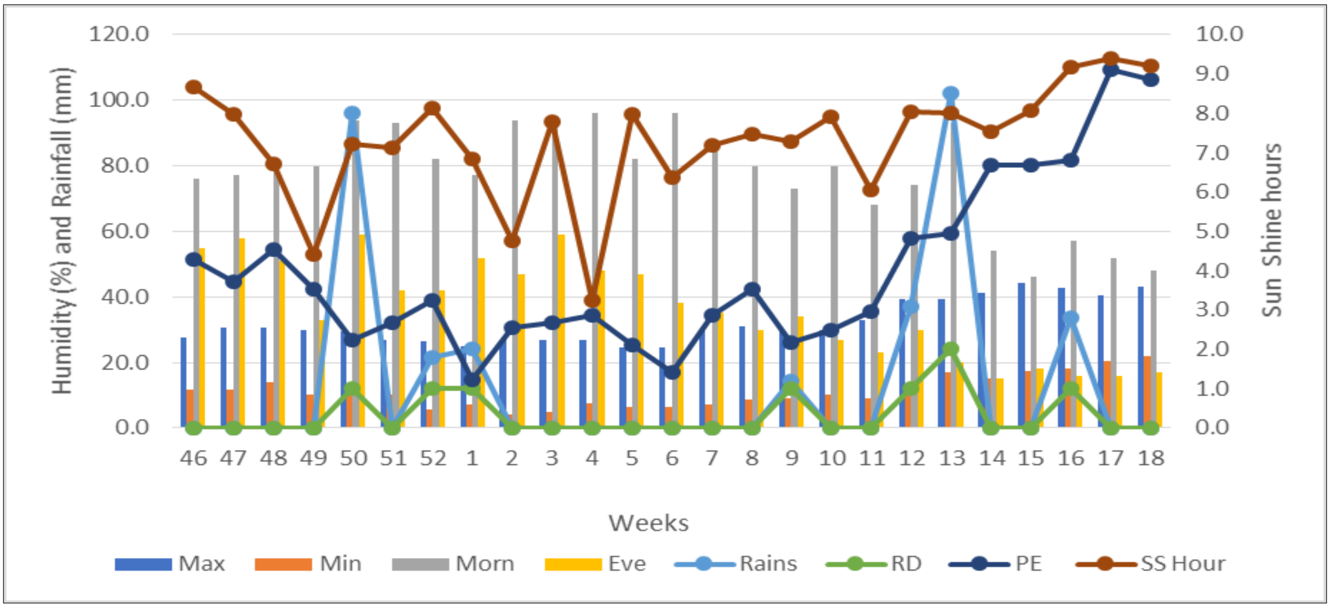

Fig 1: Different weather elements during crop season 2019-20

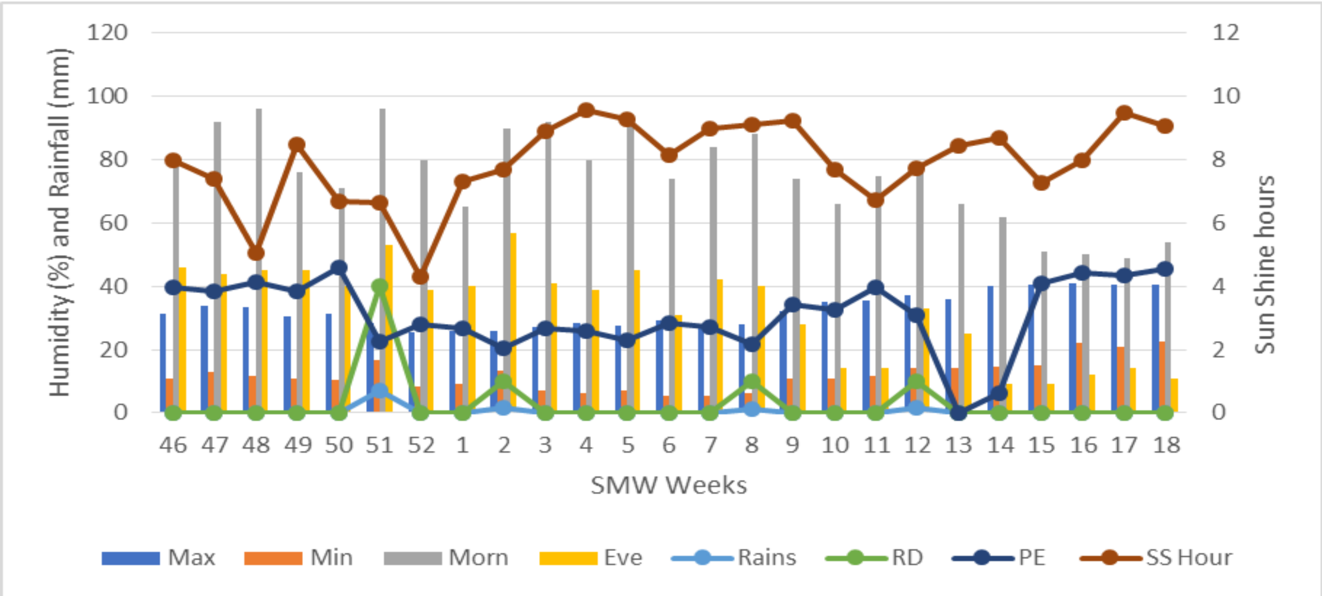

Fig 2: Different weather elements during crop season 2020-21

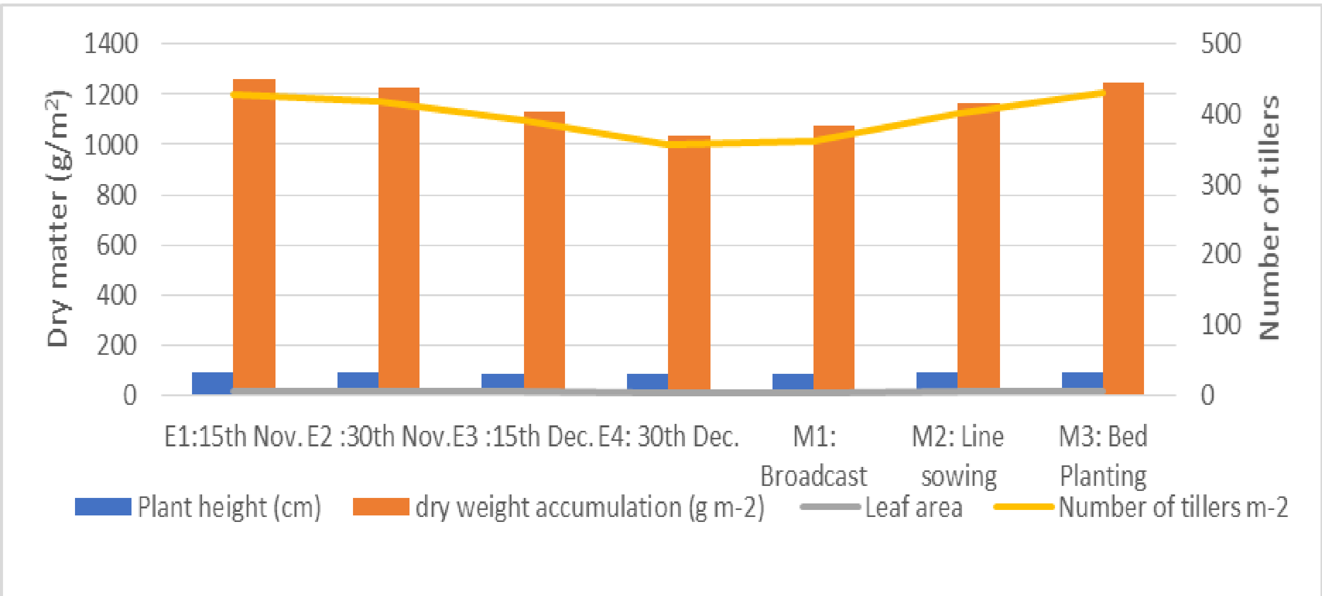

Fig 3: Dry matter and number of tillers of wheat as influenced by Sowing environments & methods

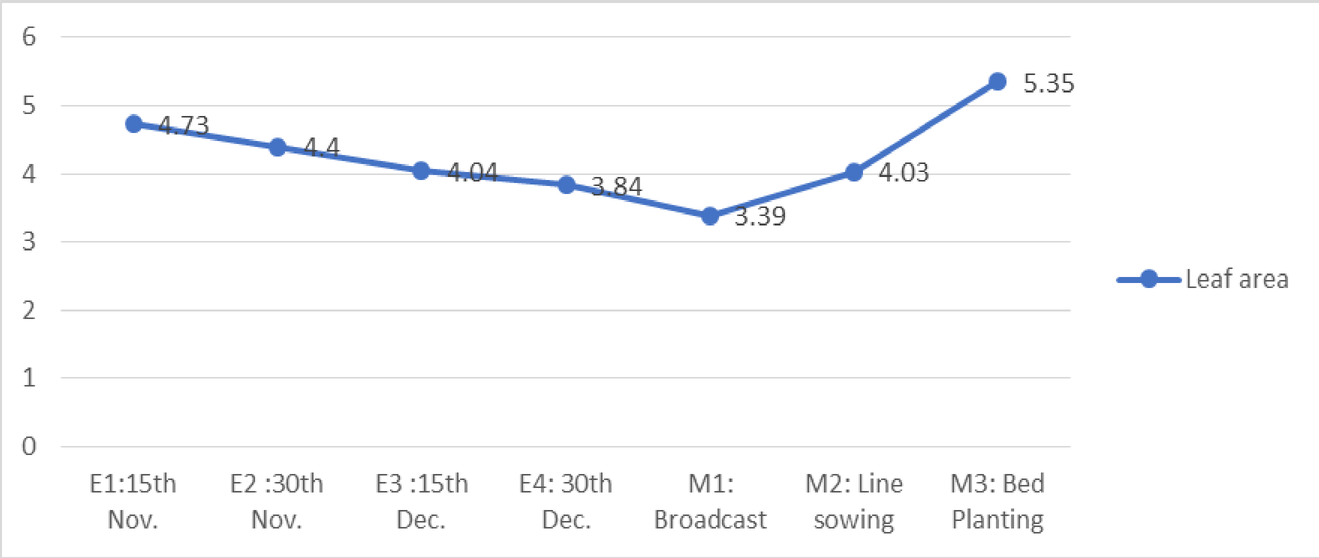

Fig 4: Growth characters & LAI of wheat as influenced by Sowing environments & methods

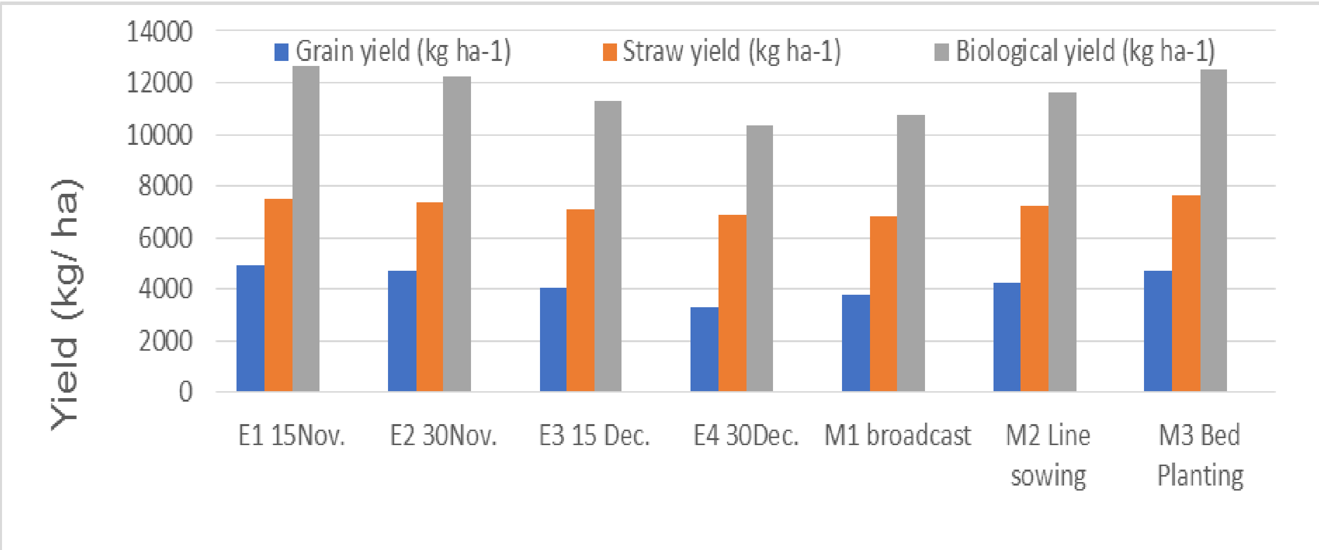

Fig 5: Grain, straw, biological yield of wheat as influenced by Sowing environments and methods

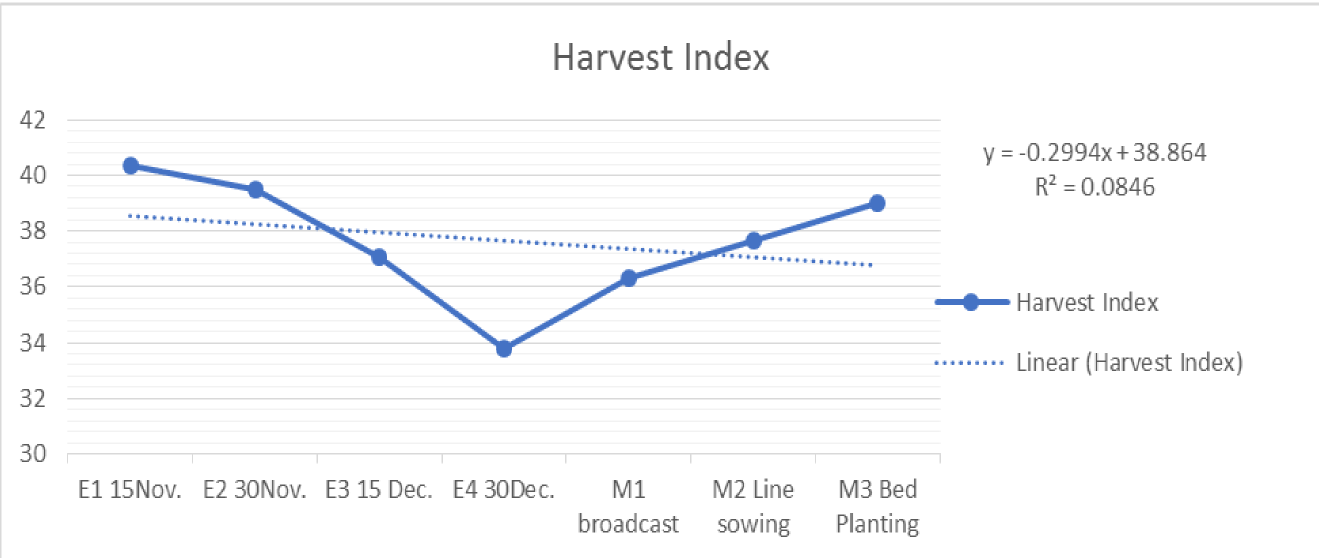

Fig 6: Harvest Index of wheat as influenced by sowing environments and methods

Conclusion

Hence, it may be concluded that to achieve the optimum production harvest index LAI, and growth parameters are significantly superior of E_1 15th November environment and bed planting method was proved to be the most and effective techniques of wheat production in Tawa command area of

Madhya Pradesh. Wheat is being photo-thermosensitive crop, selected of suitable wheat variety for different sowing time with suitable Sowing methods and other agronomic management will further get prime importance.

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