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THERMO-HYGRO ENVIRONMENT, GROWTH AND YIELD OF WHEAT UNDER VARYING SOWING TIMES AND PLANTING SYSTEMS

1. India is a vast country covering the entire climatic spectrum. The amount of rainfall received in different parts of the country is highly variable, erratic, uncertain and unevenly distributed. In addition, various geographical situations present a large difference in temperature, sunshine and wind velocity. This climatic mosaic leads to varied agro-ecological situations in the country. The varied environmental parameters influence plant growth and consequently the crop productivity. Crop productions involve a complex interaction between crop genotype, the soil and the aerial environment and crop management practices. Information on crop-weather relation is very important for deciding the adoption of particular technology and agro-management practice to enhance and sustain agricultural productivity which have profound impact on food availability and socio-economic conditions of the people in general and farming community in particular. The cultural operations for farm management have evolved through its adoption to prevailing climate and weather by the farmer through his long experience. The genetic scenario has since changed leading to the evolution of high yielding varieties which have more stringent climatic requirements. Studies on crop micro-climate / field level experiments can provide valuable information regarding the interaction of the crop with its immediate environment. The crop geometry may also affect the crop environment and its yield It varies from top of crop canopy to ground surface and affects the crop development and yield.

The sowing time and planting system are two most important variables which modify the crop environment and consequently growth, development and yield of wheat. Crop development is described in terms of the different phenological phases the crop has to go through before it completes life cycle. Delayed sowing of wheat crop is exposed to sub-optimal temperatures at establishment and supra optimal temperature at reproductive phases resulting into reduction of not only crop duration but also the yield (Sardana *et al*., 1999). Ram Niwas *et al*. (1989) and Bishnoi *et al*. (1996) have reported that crop microclimate is quite different than the open observatory in Brassica and wheat, respectively affecting the crop productivity. But, information on effect of planting systems on thermo-hygro environment of crops in general and wheat in particular is lacking. As such, the present study was conducted to quantify these relations.

2. A field experiment was conducted during two consecutive *rabi* seasons of 2002-03 (1st) and 2003-04 (2nd) at the research area of the Department of Agronomy, CCS Haryana Agricultural University Hisar, India (29° 10′ N latitude, 75° 46′ E longitude and altitude of 215.2 meters above mean sea level) to study thermo-hygro environment, growth and yield of wheat. The wheat variety WH-711 was sown on two dates *i.e.*, D_1- 20th November and D_2 -20th December and two planting systems *i.e.*, P_1- Flat bed and P_2- Furrow irrigated raised bed planting system in main plot and three nitrogen levels *i.e.*, N_1-120 kg N/ha, N_2- 150 kg N/ha and N_3-180 kg N/ha in sub plots treatments in split plot design with four replications.

For leaf area measurement the plants were uprooted from each plot and the leaves were detached and leaf area was obtained using leaf area meter at important phenophases [crown root initiation (CRI), booting, milking and physiological maturity]. The same plant samples were used for assessing the dry matter. The yield and yield attributes were recorded at the time of harvest.

Dry and wet bulb temperatures were recorded on diurnal basis at important phenological stages during 0800-1600 hours (IST) at three levels of crop canopy: ground, 50cm and 100cm inside the crop canopy and these values were used to derive daily relative humidity and vapour pressure values.

Vapour pressure deficit (VPD) was calculated using the formula:

$$VPD = SVP-AVP$$

Where,

SVP is saturated vapour pressure (AVP/RH) × 100, AVP is actual vapour pressure and RH is relative humidity.

The data on temperature, relative humidity and vapour pressure deficit were averaged at different phenophases for different day times and canopy levels. Critical difference (CD) at 5 per cent was determined by through statistical analysis described by Gomez and Gomez (1984).

3. The data on ambient temperature, humidity and vapour pressure deficit were measured at different phenophases during both years and are presented in Table 1. Among both sowing times, no much difference was observed in temperature and vapour pressure deficit at CRI but relative humidity was lower during 2002-03 (1st crop season) and higher during 2003-04 (2nd crop

TABLE 1

Effect of sowing times and planting systems on thermo-hygro parameters in wheat under different nitrogen levels at different phenological stages in wheat

Treatments	CRI			Booting			Milking			Physiological Maturity		
	*T*a (°C)	RH (%)	VPD (mm of Hg)	*T*a (°C)	RH (%)	VPD (mm of Hg)	*T*a (°C)	RH (%)	VPD (mm of Hg)	*T*a (°C)	RH (%)	VPD (mm of Hg)
						2002 - 2003						
D_1	16.3	72.1	5.5	21.7	76.2	4.9	23.8	64.8	8.8	28.4	46.4	17.5
D_2	16.3	64.4	5.3	26.0	65.8	7.8	26.7	52.6	13.4	33.8	36.2	28.0
P_1	16.3	70.2	5.4	22.6	71.7	6.3	25.4	60.1	11.1	31.2	42.2	23.1
P_2	16.3	67.1	5.4	25.1	69.5	6.5	25.2	58.0	11.1	31.0	40.5	22.4
N_1	16.2	65.8	5.1	26.4	68.0	6.4	25.5	55.3	12.1	31.0	40.1	22.7
N_2	16.5	69.5	5.6	22.7	70.5	6.2	25.3	59.0	10.5	31.1	41.9	22.7
N_3	16.2	71.6	5.4	22.5	74.0	6.5	25.0	62.3	10.6	31.2	43.1	22.9
SD ±	0.10	2.95	0.16	1.92	3.53	0.84	0.85	4.11	1.43	1.56	3.12	3.04
						2003 - 2004						
D_1	13.8	71.3	4.0	22.2	73.3	6.2	27.1	74.0	7.7	31.2	45.5	20.4
D_2	13.3	84.2	2.2	27.2	73.6	7.8	29.5	56.5	14.6	37.2	24.0	37.9
P_1	13.5	78.0	3.1	24.6	74.1	6.9	28.1	66.7	10.5	34.2	35.3	28.8
P_2	13.6	77.5	3.1	24.8	72.9	7.2	28.5	63.8	11.8	34.2	34.2	29.5
N_1	13.7	78.0	3.0	24.8	72.3	7.3	28.4	63.9	11.6	34.5	34.5	29.4
N_2	13.5	77.3	3.2	24.7	73.8	6.9	28.5	64.1	11.6	34.5	34.2	29.6
N_3	13.5	78.0	3.1	24.6	74.3	6.8	28.0	67.8	10.2	33.6	35.6	28.5
SD ±	0.16	3.73	0.52	1.45	0.70	0.49	0.72	5.28	2.08	1.76	6.23	5.07

*T*a- Air temperature, RH- Relative humidity, VPD- Vapour pressure deficit

TABLE 2

Effect of sowing times and planting systems on leaf area index in wheat under different nitrogen levels

Treatments	CRI		Booting		Anthesis		Milking		Physiological maturity	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
D_1	0.40	0.36	3.10	2.89	4.38	4.08	2.79	2.68	0.87	0.80
D_2	0.36	0.31	2.73	2.51	3.85	3.67	2.44	2.31	0.69	0.63
CD at 5%	0.03	0.03	0.16	0.13	0.15	0.10	0.15	0.18	0.07	0.07
P_1	0.39	0.35	3.00	2.77	4.19	3.93	2.70	2.59	0.82	0.76
P_2	0.36	0.32	2.83	2.62	4.04	3.83	2.54	2.40	0.74	0.67
CD at 5%	0.03	0.03	0.16	0.13	0.15	0.10	0.15	0.18	0.07	0.07
N_1	0.33	0.29	2.52	2.32	3.45	3.35	2.54	2.19	0.56	0.50
N_2	0.39	0.34	3.03	2.79	4.28	3.90	2.31	2.51	0.79	0.73
N_3	0.41	0.36	3.20	2.98	4.61	4.38	2.66	2.78	0.99	0.92
CD at 5%	0.02	0.02	0.14	0.11	0.14	0.08	0.14	0.15	0.06	0.05

TABLE 3

Effect of sowing times and planting systems on dry matter (g m^{-2}) in wheat under different nitrogen levels

Treatments	CRI		Booting		Anthesis		Milking		Physiological maturity	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
D_1	6.0	5.3	395.4	352.2	641.6	603.4	801.3	737.2	1085.7	985.3
D_2	4.0	4.1	275.6	251.6	511.3	507.0	680.4	617.2	931.8	872.7
CD at 5%	0.04	0.06	23.7	23.1	35.2	28.4	46.3	46.9	28.0	21.0
P_1	5.3	5.1	360.9	314.7	595.8	570.3	768.4	701.8	1025.8	947.3
P_2	4.7	4.3	310.1	289.1	557.1	540.0	713.3	652.6	991.7	910.7
CD at 5%	0.04	0.06	23.7	23.1	35.2	28.4	46.3	46.9	28.0	21.0
N_1	4.3	3.9	271.9	238.6	500.6	475.6	650.1	580.7	917.2	840.5
N_2	5.0	4.5	343.9	308.7	577.4	557.6	757.2	689.4	1032.9	942.2
N_3	5.6	5.7	390.6	358.4	651.5	632.3	815.3	761.6	1076.2	1004.3
CD at 5%	0.03	0.04	21.9	20.0	31.1	21.6	42.8	40.6	25.0	25.0

TABLE 4

Effect of sowing times and planting systems on plant height, yield attributes and yield in wheat under different nitrogen levels

Treatment	Plant height (cm)		No. of grains/ear		Test weight (g)		Grain yield (q/ha)	
	2002-2003	2003-2004	2002-2003	2003-2004	2002-2003	2003-2004	2002-2003	2003-2004
D_1	83.7	80.3	49.8	48.0	43.0	42.0	51.3	46.2
D_2	77.4	74.4	43.1	41.2	40.5	39.4	44.4	40.2
CD at 5%	1.3	1.7	1.7	1.5	1.0	0.6	0.7	0.6
P_1	79.1	76.3	44.7	42.9	40.9	39.9	48.6	44.1
P_2	82.1	78.4	48.2	46.3	42.6	41.5	47.0	42.4
CD at 5%	1.3	1.7	1.7	1.5	1.0	0.6	0.7	0.6
N_1	74.6	71.4	42.6	40.8	39.1	38.1	43.6	38.8
N_2	81.2	77.6	47.1	45.2	42.3	41.3	49.0	43.9
N_3	85.9	83.1	49.7	47.8	43.9	42.8	50.9	47.0
CD at 5%	1.9	1.8	1.5	1.7	NS	NS	0.8	1.0

season) in D_2 as compared D_1 at this stage. At rest of phenophases temperature and vapour pressure deficit were higher in D_2 as compared to D_1, whereas relative humidity showed a reverse trend. Air temperature showed no clear trend among planting systems at all the phenophases but relative humidity was lower in P_2 as compared to P_1 at all the phenophases. The air temperature and VPD did not show much variation among nitrogen levels, but relative humidity markedly increased with increase in nitrogen application at all the phenophases. The air temperature and VPD were increased with advancement of season and higher at physiological maturity in all the treatments, while relative humidity decreased with advancement in season and lower at physiological maturity.

Leaf area index was recorded at all phenophases in both crop seasons and data are presented in Table 2. The leaf area index of wheat increased with the advancement of crop age up to anthesis during both the years in all the treatments and decreased thereafter due to senescence of leaves. 20th November sown crop produced more leaf area index at all growth stages during both crop seasons as compared to 20th December sown crop. Maximum value of LAI was 4.38 and 4.08 in normal date of sowing (20th

November) during 1st and 2nd crop seasons, respectively. The sowing on raised beds resulted less LAI values as compared to flat bed sowing at all the phenological stages during both crop seasons. The leaf area index was higher in all the treatments during 1st crop season as compared to 2nd crop season. LAI values were statistically at par between both planting systems. Among the nitrogen levels, higher LAI was observed in 180 kg ha^{-1} nitrogen fertilized crop at all phenological stages during both years.

The data on dry matter production (g m^{-2}) under various treatments are presented in Table 3. Dry biomass increased with the advancement of crop stage and maxima was observed at physiological maturity in all the treatments. Among the sowing dates, more dry matter was produced by 20th November sown crop as compared to 20th December sown crop at all phenophases during both crop seasons. The data on dry matter production revealed that the dry biomass was higher in conventional planting system in comparison with bed planting system. The maximum dry matter production of 1085.7 and 985.3 g m^{-2} was recorded with flat bed sowing in 2002-03 and 2003-04, respectively. The increase in dry matter production with increasing N levels was observed in both crop seasons up to 180 kg N ha^{-1}.

The delay of the sowing significantly reduced the plant height as compared to timely sown crop in both crop seasons (Table 4). Plant height increased with nitrogen application in wheat and maximum was recorded at 180 kg N ha^{-1}.

The data in Table 4 clearly show that delay in sowing of wheat crop resulted in significant reduction of number of grains per ear as compared to normal sown crop in both years. The furrow irrigated ridge bed method of planting showed higher number of grains per ear and test weight in both crop seasons as compared to flat sowing. Number of grains per ear and test weight improved with each increasing level of nitrogen and maximum were obtained with 180 kg N ha^{-1}. Maximum grain yield was recorded in 20th November sown wheat crop in both crop seasons. The grain yield was marginally higher under conventional method of sowing as compared to furrow irrigated ridge bed planting system. The grain yield increased significantly with progressive increase in fertilizer level up to 180 kg N ha^{-1}in both the years.

4. Air temperature and vapour pressure deficit were higher in 20th December sown crop as compared to 20th November sown wheat except at crown root initiation whereas relative humidity was lower in late sown wheat crop. This might be because of inverse relationship between temperature and relative humidity. Maximum value of LAI was 4.38 and 4.08 in normal date of sowing during 2002-03 and 2003-04, respectively probably due to cool temperature and low vapour pressure deficit in this sowing environment. Singh and Pal (2003) also reported that the delay of sowing decreased the leaf area index at all growth stages significantly. 20th November sown crop produced more dry matter as compared to 20th December sown crop at all phenophases and this might be due to higher LAI and lower temperatures prevailed in first sowing date during both the crop seasons. Dogiwal *et al.* (2003) also observed that total plant biomass was reduced significantly at all growth stages with delay in sowing. The higher plant height under normal sown was attributed to favourable cool weather prevailed in this sowing environment which might result in more cell division and cell elongation. Taller plants were observed in bed planted wheat than that of flat sowing due to border effect. Yadav *et al.* (2002) also recorded higher values of plant height under furrow irrigated raised bed planting system as compared to flat sowing method.

The reduction in number of grains per ear and test weight under late sowing wheat was due to the fact that grains ear^{-1} were sensitive to increase in temperature during the reproductive period in delayed sowing. Kulheri *et al.* (2003) also reported that number of grains per ear were higher in normal sown crop as compared to late sown wheat. The decrease in grain yield with delay of sowing was attributed to higher air temperature and vapour pressure deficit experienced during grain development phase by wheat crop which ultimately resulted in forced maturity. Singh *et al.* (2003) also reported that delayed sowing significantly reduced the grain yield. Higher grain yield of wheat recorded in 1st crop season in all the treatments might be due to longer period for grain filling and favourable temperature and humidity as compared to 2nd crop seasons. The grain yield was marginally higher under conventional method of sowing might be due to favourable hygro-thermal environment, which in turn resulted in increased leaf area index as well dry matter and grain yield. Jat and Singhi (2003) also reported that flat planting system produced some more grain yield as compared to furrow irrigated ridge bed planting system.

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