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Effect of Sowing Methods and Nitrogen Management on Yield and Agro- metrological Indices on Wheat (*Triticum aestivum* L.)

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ABSTRACT: Wheat is more sensitive toward climate change. Reasing temperature causing yield reduction specially in late sown wheat. Consider this fact a field experiment was conducted during *rabi* seasons of 2017-18 and 2018-19 at Agronomical research farm, Acharya Narendra Deva University of Agriculture and Technology, Ayodhya, India, to study on agro-meteorological indices, grain and straw yields and their relationships with each other, the experiment comprised of four sowing methods *viz.* broadcasting sowing (Bs), line sowing (Ls), furrow irrigation ridge bed (FIRB) and criss cross sowing (20 × 20 cm) (Cs) in main plot and five nitrogen managements treatments *viz.*, control (N_0), 50% N as basal + 25% N after first irrigation + 25% N after second irrigation (N_1), 50% N as basal + 50 % N after first irrigation (N_2), 25% N as basal + 25% N after second irrigation + 50% through FYM as basal (N_3), 25% N as basal + 75% through FYM as basal (N_4) was laid out with three replication. The agro-meteorological indices, input use efficiency, grain and straw yield was recorded significantly higher with FIRB, followed by Ls and the lowest accumulated with Bs. Under nitrogen management practices, the higher agro-meteorological indices, input use efficiency, grain, and straw yield was recorded under N_1 followed by N_3 and N2 and lowest values were found with control treatment. A positive relationship was found between GDD with grain and biological yields under different sowing methods and nitrogen management treatments.

Keywords: Wheat, sowing methods, nitrogen, agro-meteorological indices, yield.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world′s most outstanding crop that excels all other cereals in area and production, known as the king of cereals. It is primarily grown in temperate regions and also at higher altitudes under tropical climate areas in the winter season. It is the single most important cereal crop that has been considered an integral component of the food security system of several nations. It ranks first among the cereals regarding area (204.34 million ha) and production (737.8 million tonnes). India has grown in 31.35 million hectares with 107.86 million tons production (USDA) (Anonymous, 2019-20).

Wheat is a long day plant. Temperature ranging between 20° to 25°C is ideal for grain sowing and germination. Whereas the optimum temperature for the vegetative growth period range from 16° to 22°C. During grain development, wheat requires a mean maximum temperature of about 25°C for at least 4-5 weeks. Wheat is grown well in those areas where annual rainfall ranges between 800 mm to 1200 mm. The low productivity of wheat in our country is mainly attributed to the delayed sowing, imbalanced and lower doses of fertilizer, the traditional method of sowing, improper selection of varieties, inadequate irrigation facilities and adverse weather conditions, etc. (Premdeep *et al.*, 2019)

In eastern Uttar Pradesh and Bihar, wheat is grown under irrigated and rainfed conditions in a rice-based cropping system. The sowing of wheat is often delayed due to delays in the sowing and harvesting of rice. The choice of sowing methods and nitrogen management with improved variety is an important management decision to optimize grain yields and economics (Bannayan *et al.*, 2003). Late sown wheat faces low temperatures in the earlier stage and high-temperature stress in the later stage of the growing season (Alam *et al.*, 2013), one of the major causes of stunted growth and low productivity of wheat in this area. Sowing methods help govern the crop phonological development and total biomass production, and the efficient conversion of biomass into economic yield (Bakht *et al.*, 2011). Abdullah *et al.*, (2008) reported that furrow and ridge planting methods significantly increased the yield of maize when compared with other planting methods. A furrow ridge bed system with several defined rows planted on top of the bed with furrow irrigation can overcome these detriments (Nasir and Akbar, 2000). Govaerts *et al.*, (2004); Wang *et al.* (2004); Ortega *et* *al.,* (2008) reported that Furrow Irrigation Ridge Bed (FIRB) is the most efficient method of planting for wheat and other crops.

Climate and weather significantly influence the crop productivity in any region controlled by the prevailing climatic conditions viz., temperature, rainfall, light intensity, solar radiation, sunshine duration, etc. (Goswami *et al.* 2006). Of all the environmental factors, the weather is the most significant essential that affects plant growth and development, especially phenology and yield (Kaur *et al.*, 2019). The heat unit or growing degree days (GDD) was projected to clarify the connection between crop growth and temperature. This perception assumes a direct and linear relationship between growth and weather. Every crop has a specific temperature range to attain phonological stages. The photo-thermal unit perception delivers a dependable index for crop development that can predict the yield of several crops (Pal *et al.,* 2013). Though GDD and photo-thermal units (PTU) accumulation for every developing phase is relatively constant (Phadnawis and Saini, 1992), certain agronomical management practices could modify them.

Nitrogen is the most critical nutritional element required by plants. The balanced use of nitrogenous fertilizers and manure prolongs phenol phases and consequently needs more heat units than the crop supplied with a smaller amount of N fertilizer Ram *et al.*, (2012). Nitrogen availability at later growth stages has also been reported to extend the grain filling period and increase grain yield (Kaur and Pannu, 2008). Optimized nitrogen management through different approaches viz. optimum dose of nitrogen, time of application, integrated nitrogen management can be used for increasing yield and improving nutrient use efficiency of wheat. Considering all the above facts, the experiment was conducted to study the "Effect of weather parameter on growth and yield of wheat under different growing environment."

MATERIAL AND METHOD

A. Characterization of the experimental site

The experiment was conducted at the Agronomical research farm of the Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, (U.P.), during *rabi* seasons of 2017-18 and 2018-19. Ayodhya region falls in the North Indian belt of sub-humid climate and falls in the Indo- Gangetic plains with an alluvial soil and lies between latitude 26.470 North and longitude 82.120 East an elevation of about 113 meters from sea level and is subjected to extremes of weather conditions. During peak summers of May and June, the temperature was around 40 to 45°C. The temperature dropped from early November, touching a minimum of less than 5°C during December and January. The data on climatic parameters such as rainfall, mean maximum, minimum temperature, relative humidity, sunshine, and wind speed was recorded at the Meteorological Observatory, Meteorology Research Farm ANDUA & T, Kumarganj, Ayodhya have been graphically depicted in Fig. 1. The total rainfall during the crop growth period in 2017-18 was 9.80 mm, while during 2018-19, it was 43.00 mm. During the crop growth period, the maximum temperature ranged from 20.5°C to 39.2°C during 2017-18 and from 21.2°C to 37.2°C during 2018-19. The minimum temperature during 2017-18 ranged from 4.7°C to 15.1°C, while during 2018-19, it was 5.0°C to 22.5°C.

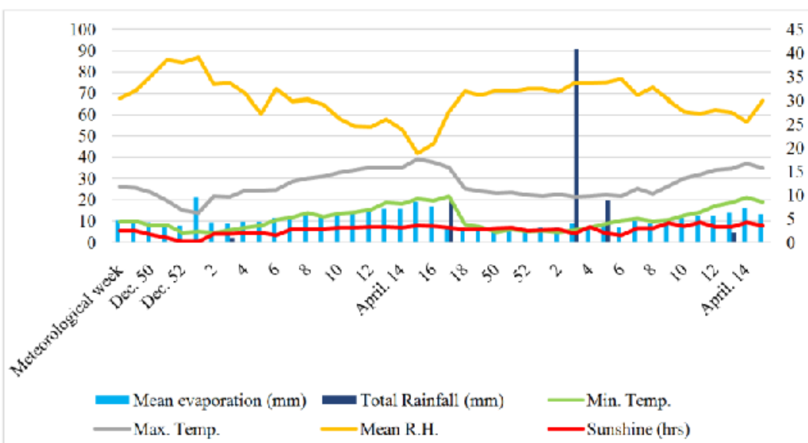

Fig. 1. Meteorological condition of experimental field during experiment.

B. Description of experimental design, treatments, and agrometeorological indices

The field experiment was conducted for two consecutive years, starting from the *rabi* season of 2017-18. The experiment was laid out in Split Plot Design (SPD), consisting of 20 treatments. Treatments comprised of all possible combinations of four sowing methods as main plot treatments *viz.* broadcasting sowing (Bs), line sowing (Ls), furrow irrigation ridge bed (FIRB), and criss-cross sowing (20 × 20 cm) (Cs) in the main plot and five nitrogen managements treatments *viz.*, control (N_0), 50 % N as basal + 25 % N after first irrigation + 25 % N after second irrigation (N_1), 50 % N as basal + 50 % N after first irrigation (N_2), 25 % N as basal + 25 % N after second irrigation + 50 % through FYM as basal (N_3), 25 % N as basal + 75 % through FYM as basal (N_4) as subplot treatment was laid out with three replication Fig. 2.

Fig. 2. Photos of experimental field at sowing stage and at the time of tillering.

Nitrogen was applied as per the treatments by FYM and urea at the rate of 120 kg ha^{-1} and other fertilizers were applied at the rate of 60 and 40 kg ha^{-1} of P_2O_5 and K_2O, respectively. Single super phosphate (SSP) and Murate of potash (MOP) were used as phosphorus and potassium sources, respectively. All doses of SSP and MOP fertilizers were applied at the time of sowing, and nitrogen was applied as per the treatment. Sowing was done on 7 December in both the year of experimentation. Six irrigations were applied in 2017-18 and 2018-19, respectively. Data related to occurrences of phenological proceedings (when 50 percent of plants in the plots had got the respective stage) was noted based on visual observations and analyzed later. The day-to-day meteorological data and days taken to phenological stages were used to compute the agro-meteorological indices like growing degree days (GDD), helio-thermal units (HTU) as suggested by Monteith, (1984) whereas, phenol thermal index (PTI) were computed as indicated by Singh *et al.,* (2008) and heat use efficiency (g/m^{-2}/0 day) were calculated following Islam and Sikdar (2011).

C. Statistical analysis

Data were analyzed statistically to analyze variance (ANOVA) following the methods described by Gomez & Gomaz (1984). The significance of differences among means was compared by using Least Significant Difference (LSD) test (Steel and Torrie, 1997).

RESULTS AND DISCUSSION

A. Phenology and growth

Days to emergence were significantly ($p<0.05$) affected by various sowing methods and nitrogen management. Bs took maximum days to emergence while FIRB recorded minimum days to emergence. It could be due to the different sowing depths of grain provide a favorable environment for quick germination. The data also revealed that days to emergence were less in N_4 followed by N_3 than other treatments. The probable reasons could be the higher organic matter which supplied essential nutrients for quick emergence. Our result also showed that days to full stem elongation, days taken to anthesis, days taken to physiological maturity, and days taken to harvest maturity were significantly ($p<0.05$) affected by sowing methods and nitrogen management. At the same time, their interaction was non-significant ($p>0.05$). FIRB took more days while Bs took fewer days to stem elongation, days taken to anthesis, days taken to physiological maturity, and days taken to harvest maturity. It could be due to the favorable interaction found between sowing methods and the environment. Sowing methods provide a better environment for the growth and development of the crop. These results are in line with the findings of Yagmur and Kaydan (2009). Siddique and Bakht (2005) also reported a similar work, who investigated that days to tasseling and silking were more in-furrow and ridge method in maize crop. Bakht *et al.,* (2011) The highest number of days to silking were recorded in the ridge method, while lowest in the broadcast sowing method.

In nitrogen management, more days to full stem elongation, days taken to anthesis, days taken to physiological maturity, and days taken to harvest maturity reported by N_1 followed by N_3, while less by control. It could be due to delayed booting, milk, anthesis, and maturity stage in nitrogen fertilized treatments attributed to increased leaf area duration, enlarged vegetative growth, and enlarged light use efficiency with an increase in nitrogen Deldon (2001), Khan *et al.* (2008). The additional availability of nutrients and good soil conditions due to organic sources of nitrogen, which resulted in vigorous crop growth, might have extended the growing period (Liu and Yong, 2008), thus delaying phenology. The prolonged stages of days to maturity due to N application rates and time were reported by Dolan *et al.,* (2006), who showed that higher nutrient availability and favorable soil conditions due to N fertilizer could be a possible reason for delayed phenology N-treated plots. Namvar and Seyed Sharifi (2011) reported that increasing N rates significantly delays the duration of the vegetative and reproductive period, which is proof of the lengthening of the time to maturity. Sharifi and Namvar (2016) showed that the maximum days to 50% tasseling, days taken to 50% silking, days to physiological maturity were observed in the plots treated with 225 kg N ha^{-1}.

Table 1: Effect of sowing methods and nitrogen management on phenological stages of wheat (*Triticum aestivum* L.)

Treatment	Days taken to emergence		Days taken to stem elongation		Days taken to anthesis		Days taken to physiological maturity		Days to maturity	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Sowing methods										
Bs	6.43	6.55	41.96	42.79	69.89	71.14	103.82	103.68	127.80	122.27
Ls	5.93	6.02	46.07	45.92	74.40	75.56	104.33	103.74	129.40	123.87
FIRB	5.09	5.33	46.08	46.40	74.64	75.31	104.20	105.55	130.93	127.27
Cs	7.01	6.82	42.41	43.08	70.63	71.30	102.39	102.78	128.39	123.71
SEm ±	0.25	0.24	0.73	0.23	0.83	0.51	0.47	0.96	0.44	0.60
LSD (≤0.05)	0.88	0.83	2.52	0.78	2.86	1.75	1.63	3.31	1.53	2.08
Nitrogen management										
N_0	7.29	6.94	40.76	41.45	68.65	68.84	101.42	99.38	126.91	118.18
N_1	5.68	5.93	48.11	47.81	77.21	78.17	107.16	109.33	132.21	130.08
N_2	6.38	6.38	43.95	44.51	72.13	72.84	102.93	103.32	128.21	124.48
N_3	5.64	5.85	45.95	46.59	74.22	76.81	104.84	106.10	130.97	127.17
N_4	5.58	5.79	41.88	42.38	69.75	69.99	102.08	101.57	127.34	121.49
SEm ±	0.23	0.17	0.63	0.55	0.61	0.72	0.83	0.91	0.64	0.64
LSD ≤0.05)	0.67	0.48	1.83	1.59	1.76	2.06	2.38	2.63	1.85	1.85

B. Growing degree days and Helio thermal units

The heat unit or growing degree days (GDD) suggest explaining the relationship between crop growth duration and temperature. This conception assumes a direct and linear relationship between crop growth and temperature. Data on GDD and HTU are presented in Table 2. Bs took the significantly maximum heat unit or growing degree days (GDD) at the emergence stage, while FIRB recorded minimum days to emerge. Due to the different sowing environments absorb different temperatures in nitrogen management at the emergence stage, higher GDD, and HTU was taken by control than other treatment. FIRB accumulated more heat units or GDD and HTU followed by Ls at different phenological stages than other sowing methods to attain different phonological stages. The differential sowing methods changes the environment of the wheat crop and effects on heat unit requirements and HTU. Besides, it was also due to increase nutrient use efficiency and moisture availability increase the duration of crop under the FIRB method to complete its growth compared to the broadcasting method of sowing. Methods of sowing variation for accumulation of GDD to achieve different phenology has also been reported by Ortega *et al.*, (2008).

Table 2: Effect of sowing methods and nitrogen management on agro-metrological indices of wheat (*Triticum aestivum* L.).

Treatment	Photo Thermal Unit		Photothermal index		HUE for seed yield		HUE for straw yield	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Sowing methods								
Bs	2644567	2379554	18.40	17.22	0.0103	0.0111	0.0133	0.0152
Ls	2692772	2365856	18.51	17.36	0.0140	0.0174	0.0179	0.0216
FIRB	2774209	2663000	18.63	17.62	0.0166	0.0179	0.0207	0.0224
Cs	2521210	2449153	18.43	17.35	0.0121	0.0122	0.0152	0.0155
SEm ±	84989	48800	0.03	0.05	0.0011	0.0010	0.0012	0.0008
LSD (≤0.05)	NS	168869	0.12	0.16	0.0037	0.0033	0.0042	0.0028
Nitrogen management								
N_0	2513386	2225550	18.32	16.88	0.0079	0.0094	0.0101	0.0119
N_1	2847633	2720953	18.74	17.90	0.0163	0.0170	0.0204	0.0216
N_2	2604717	2365634	18.42	17.36	0.0131	0.0150	0.0167	0.0190
N_3	2860087	2663870	18.63	17.64	0.0162	0.0178	0.0207	0.0225
N_4	2465124	2345945	18.34	17.16	0.0126	0.0142	0.0160	0.0183
SEm ±	83757	92158	0.05	0.05	0.0006	0.0005	0.0007	0.0005
LSD (≤0.05)	241275	265476	0.14	0.15	0.0016	0.0013	0.0021	0.0015

Under nitrogen management, N_1 accumulated the highest number of heat units and HTU compared to other nitrogen management treatments at all the phonological stages. Because the split application of nitrogen had increased the nitrogen use efficiency that increases the number of calendar days and thermal time of the crop, which in turn increased GDD and HTU, these findings are in confirmatory with the results of Malo and Ghosh (2018); Kaur *et al.*, (2019). FIRB, like other sowing methods, recorded higher photo thermal unit (PTU), photo-thermal index (PTI), and HUE values. Under nitrogen management N_1 followed by N_3 accumulated the highest PTU, PTI, and HUE values compared to other nitrogen management treatments. The split application and integrated use of nitrogen had increased the nitrogen use efficiency that increased the grain and straw yield of the crop, which increased PTU, PTI, and HUE. These findings confirm the results of Malo and Ghosh (2018); Kaur *et al.*, (2019).

Table 3: Effect of sowing methods and nitrogen management on Heliothermal units (°Day hour) at different phenological stages of wheat (*Triticum aestivum* L.)

Treatment	Emergence		Full stem elongation		Anthesis		Physiological maturity		Harvest maturity	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Sowing methods										
Bs	4358	4690	76769	166199	248753	443385	722725	986121	1479327	1754886
Ls	3662	3652	92678	190915	287520	506645	799686	1105527	1532397	1823788
FIRB	2582	2858	93100	196256	288552	500249	744111	1148143	1589300	1973062
Cs	5104	5132	77222	167346	253109	444147	752625	1053633	1498002	1820629
SEm ±	349	306	3008	1619	6593	6000	28025	22656	15379	23519
LSD (≤0.05)	1208	1059	10409	5603	22813	20763	NS	78398	53220	81385
Nitrogen management										
N_0	5571	5378	72958	155128	236317	417317	658366	969005	1447790	1597273
N_1	3244	3771	101330	207130	315535	540055	840256	1218013	1634020	2090745
N_2	4180	4293	83760	180037	264250	463571	749156	1047074	1491869	1833666
N_3	3365	3519	91224	196403	285892	518876	781986	1120665	1589504	1968280
N_4	3272	3453	75440	162196	245422	428213	744169	1012024	1460599	1725492
SEm ±	353	223	2653	4352	5246	9359	31850	17164	22166	27810
LSD (≤0.05)	1017	642	7642	12536	15111	26961	91749	49445	63853	80112

C. Grain and straw yields (q/ha)

Grain and straw yield of wheat crops varied significantly due to different planting methods, and nitrogen management treatments are presented (Table 4). The grain and straw yield of wheat remained affected by the other planting methods during the experimentation years. FIRB recorded significantly higher grain yield, which was at par with the line sowing method. Whereas Cs method of planting at par with broadcasting. Bs recorded substantially lower grain yield. The same trend was observed in both years of experimentation. These results align with Dawelbeit and Babiker (1997). They reported that sowing by a grain drilling and ridging after broadcasting resulted in significantly greater yields than broadcasting alone for the two seasons. Also, these results agree with Abbas *et al.,* (2009).

Table 4: Effect of sowing methods and nitrogen management on yield of wheat (*Triticum aestivum* L.).

Treatment	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	2018	2019	2018	2019
Sowing methods				
Bs	24.23	23.50	31.25	32.24
Ls	33.60	38.43	43.04	48.55
FIRB	40.74	39.54	50.74	49.01
Cs	28.66	26.40	36.07	33.43
SEm ±	2.49	1.82	2.85	1.69
LSD (≤ 0.05)	8.63	6.29	9.86	5.84
Nitrogen management				
N_0	18.48	18.69	23.45	23.81
N_1	40.49	39.14	50.73	50.53
N_2	32.16	33.77	40.97	42.86
N_3	38.41	38.50	48.89	48.70
N_4	29.50	29.73	37.33	38.14
SEm ±	1.39	1.03	1.76	1.06
LSD (≤0.05)	3.99	2.97	5.07	3.04

Wheat grained under different nutrient management showed significant variation in grain and straw yield. The N_1 produced significantly higher grain yield compression to other treatments, which was at par with N_2. Whereas the N_3 was the second-best treatment followed by N_2. A considerably lower yield was observed with the application of 0 kg N per ha (control). The highest harvest index (HI) and test weight (g) values were observed with FIRB in the main plot and N_1. These results are in line with Meena *et al.,* (2018), who found that grain yield of wheat was significantly higher in FYM either alone or in combination with NPK than in control plots, and Similar was the trend in straw yield. Pravalika and Gaikwad (2021) the higher rate of nitrogen recorded higher dry matter yield of oat. Kumar *et al.,* (2021) FYM in conjuction with chemical fertilizers application may carry essential nutrients for crops for long term to enhanced the growth of crops and improved soil frtility through nutrient cycling.

D. Relationship between heat unit and grain and biological yields

The final yield of crop depends on amount of heat units accumulated during their life period. There is highly positive correlation between accumulation heat unit with grain and biological yields (R2 = 0.714). Accumulation heat unit days explained 61.73 percent variation in grain yield and 66.94. percent variation in biological yield as shown in linear equation in Figs. 3 and 4. The same finding suggest by Basu *et al.,* (2012); Torabi *et al.,* (2011) who concluded that three was highly significant correlation between thermal heat unit or GDD and yield. Al-Salim *et al.,* (2017) developed a regression equation which shown that the yield was highly correlated with growing degree days (R2= 0.83).

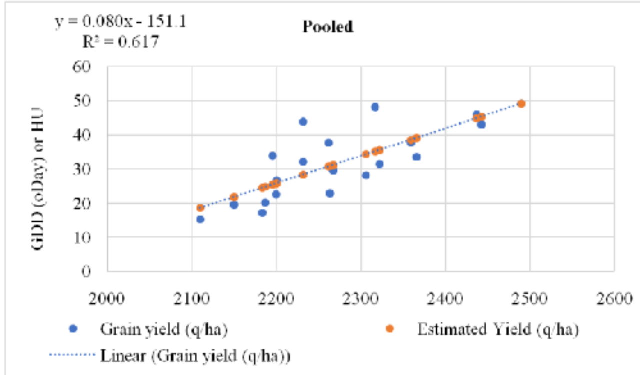

Fig. 3. Relationship between GDD and grain yield.

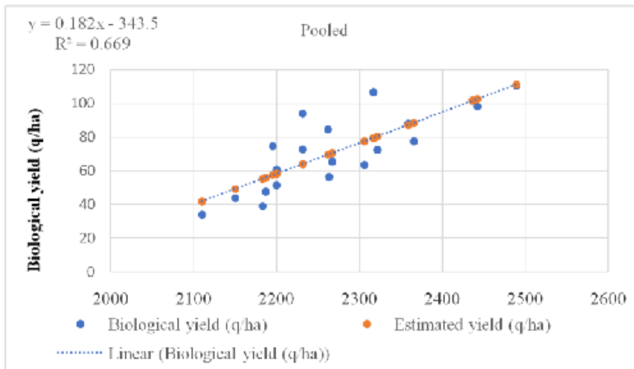

Fig. 4. Relatioship between GDD and biological yield.

CONCLUSION

The above findings concluded that higher yield, accumulated heat units, HTU, and heat use efficiency were recorded with FIRB. Among the nitrogen management, N_1 recorded higher yield, GDD, HTU, and heat use efficiency. It indicated that sowing methods and nitrogen management responded positively to yield, GDD, HTU, and heat use efficiency. Besides, application of agro-meteorological indices provides the evidence correlated to effect of temperature and solar radiation on the crop phenology, yield and heat energy consumption in wheat crop.

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Conflict of Interest. None.

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