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Research Article

Effects of Prevailing Weather Conditions on Biomass and Grain Yield of Wheat: A study through Derived Agrometeorological Indices

MEGHA[1], ABDUS SATTAR[2*], RATNESH KUMAR JHA[2], MAHESH KUMAR[3] AND BISWAJIT PRAMANICK[1*]

[1]Department of Agronomy, [2]Centre for Advanced Studies on Climate Change, [3]Department of Agricultural Statistics
Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur-848 125, Bihar

ABSTRACT

Studying the crop-weather relationship is crucial for yield optimization and risk management in a particular growing environment. In this context, a field experiment on wheat crop was conducted at Pusa (25.98°N, 85.67°E, 52 m amsl), Bihar to assess the phenophase-wise effects of weather variables and agrometeorological indices on wheat biomass and grain yield. The study employed a randomized block design, using the wheat variety DBW-187 sown on four different dates viz. 15 November, 30 November, 15 December, and 30 December, under three spacing treatments viz. 15 cm, 20 cm, and 25 cm. Correlation analyses were performed between biomass and grain yield with weather variables—temperature (maximum, minimum, and mean), relative humidity, and sunshine hours—as well as agrometeorological indices including growing degree days (GDD), helio-thermal units (HTU), and photo-thermal units (PTU) at different phenological stages. The results indicated that maximum, minimum, and mean temperatures exhibited a significant negative correlation with biomass and grain yield across major growth stages. Bright sunshine hours showed a significant positive correlation from sowing to booting, sowing to ear-head emergence, tillering, dough, and physiological maturity stages, while at the sowing to milking stage, a weaker positive correlation was observed. GDD, HTU, and PTU demonstrated a highly positive correlation with grain yield during the milking to dough stage. However, from physiological maturity to harvesting, grain yield showed a negative correlation with these agrometeorological indices.

Key words: Wheat, GDD, HTU, PTU, Yield

Introduction

Wheat (*Triticum aestivum* L.) is a very important staple food crop for a vast majority of global population. Given its flexibility to diverse climates and versatile uses, wheat is essential for maintaining both economic stability and food security. India produces 112.74 million metric tons of wheat with a productivity of 3527.5 kg ha^{-1}, which is roughly 14.24% of the worldwide output. In Bihar, wheat is grown in 2.20 M ha with a production of 6.22 million tons and productivity of 2.83 tons ha^{-1} (DES, 2022; Goutam *et al.,* 2024). Wheat crop is very sensitive to changes in weather during its growing period. The yield variation has been more prominent in recent years due to changing climate in the form of extreme temperature events. Like many other parts around the globe, the performance of wheat has been affected in the Indo-Gangetic plains due to abnormal temperature during its growing period. The current

*Corresponding author, Email: sattar.met@gmail.com (A.S.); bipra.its4u@gmail.com (B.P.)

global climate change scenario affects the agro-ecological environment, and crop growth and productivity (Basu *et al*., 2014).

The major reasons for sub-optimum output per unit area include inappropriate sowing times, incorrect variety selection, unfavorable weather during critical growth phases and traditional methods of sowing (Premdeep *et al*., 2019). Amidst backdrop of climate change, weather conditions have emerged as the paramount factor influencing crop yields. Air temperature is a crucial meteorological parameter that impacts the wheat crop's phenology and productivity (Bishnoi *et al*., 1995). According to Slafer and Rawson (1994) and Wheeler *et al*. (1996), the temperature is the primary factor determining how long a grain filling takes place in cereals. Reduced pollen viability, poor fertilization, and diminished grain formation are some important fallouts of elevated temperatures during the anthesis and grain filling stages.

The studies conducted by several authors (Sattar *et al.,* 2020; Liu *et al*., 2023; Sattar *et al*., 2023) reveal that optimal sowing timing has a profoundly positive effect on wheat growth and yield. Optimum time of sowing has profound positive influence on wheat growth and yield, whereas delayed sowing exposes the crop to unfavorable temperatures, leading to reduced emergence, premature maturity, and lower yields (Gupta *et al*., 2017). The effect of temperature on wheat crop can be effectively assessed through the concept of heat unit (Pathani *et al.,* 2019). Various agrometeorological indices, viz. growing degree day (GDD), photothermal unit (PTU), and helio-thermal unit (HUT), have enormous applications in crop growth studies, and therefore these indices are important indicators for studying crop growth (Hari Ram *et al.,* 2012; Bisht *et al.,* 2019). Keeping all these in view, in this paper, an attempt has been made to evaluate the phenophase-wise impact of weather variables and agrometeorological indices on the biomass and yield of wheat grown under different sowing dates and crop geometry.

Materials and Methods

A field experiment on wheat was conducted at Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, during the *rabi* season of 2023-24 to assess the effects of weather variables and agrometeorological indices prevailing during different growth stages of wheat on its biomass and grain yield. The experiment consisted of 12 treatments, each replicated 3 times, resulting in a total of 36 treatments. It was conducted using a randomized block design with wheat variety BW-187. The crop was sown on four different dates viz., D1 (November 15th), D2 (November 30th), D3 (December 15th) and D4 (December 30th) with three levels of spacing viz., S1 (15 cm), S2 (20 cm) and S3 (25 cm). Daily weather data such as maximum temperature, minimum temperature and sunshine hours were collected from the Agrometeorology observatory located close to the experimental field. This data was used to compute agrometeorological indices such as growing degree days (GDD), helio-thermal units (HTU) and photo-thermal units (PTU).

Growing degree-days (GDD) were computed using the following equation (Sattar *et al.,* 2023) during different phenological stages of the crop as follows:

$GDD = \Sigma\ [(T_{max} + T_{min)}/2 - T_b]$

Where, GDD = Growing degree days (day °C)

T_{max} = Daily maximum temperature (°C)

T_{min} = Daily minimum temperature (°C)

T_b = Base temperature (°C). It was taken as 10 °C (Narciso *et al*. 1992; Gowda *et al*. 2013)

Helio Thermal Units (HTU) were determined by multiplying Growing Degree Days (GDD) with the daily bright sunshine hours (BSS). The cumulative HTU for each phenophase period was computed using the equation as follows:

$HTU = GDD \times n$

Where, n = actual duration of bright sunshine hours as recorded by sunshine recorder for a particular location.

Photo Thermal Units were computed by multiplying Growing Degree Days (GDD) by the length of possible sunshine hours**.** It is mathematically expressed as

$PTU = GDD \times N$

Where, N = Maximum possible sunshine hours

A total of nineteen phenological stages of wheat were identified for the study in wheat viz. sowing to 1st emergence date, sowing to 50% emergence date, sowing to 100% emergence date, sowing to tiller initiation, sowing to booting, sowing to earhead emergence, sowing to anthesis, sowing to milking, sowing to dough, sowing to physiological maturity, sowing to harvesting, tillering, flowering, vegetative, reproductive, ripening, milking to dough, 1st emergence to harvesting and physiological maturity to harvesting (Table 1). Weather data viz. maximum temperature (T_{max}), minimum temperature (T_{min}), mean temperature (T_{mean}), temperature range (T_{range}), Bright sunshine hour (BSH), Relative humidity at 7 am (RHI), Relative humidity at 2 pm (RHII), rainfall (RF), and evaporation (evp) were collected from Agrometeorological Observatory, and prevailing during each phonological stage were worked out. Soil temperature (ST) data were recorded from the crop field. Visual observations were made to track the phenological development of wheat, and the thermal time in days required to complete each phenological stages of wheat were counted. Grain yield and biomass of wheat in kg per hectare were recorded. Correlation coefficients of grain yield and biomass with various weather parameters and derived agrometeorological indices such as growing degree day (GDD), helio-thermal unit (HTU), and photo-thermal unit (PTU) were worked out to evaluate the impact of weather on wheat biomass and grain yield.

Table 1. Duration of phase (days) of growth of wheat grown during *rabi* season of 2023-2024

S. No.	Phenophase duration	Dates of Sowing						
		15 Nov	30 Nov	15 Dec	30 Dec	Mean	S.D (±)	C.V (%)
1.	Sowing to 1st emergence date	5	6	6	7	6	1.0	15.9
2.	Sowing to 50% emergence date	7	8	9	10	8	1.1	13.7
3.	Sowing to 100% emergence date	10	10	11	12	11	1.0	9.1
4.	Sowing to tiller initiation	26	26	28	30	27	1.9	7.1
5.	Sowing to boot stage	79	78	74	72	76	3.1	4.0
6.	Sowing to ear head stage	85	83	77	75	80	4.4	5.5
7.	Sowing to anthesis	90	89	84	81	86	3.6	4.2
8.	Sowing to milking	104	100	96	92	98	7.2	6.6
9.	Sowing to dough	118	113	105	101	109	7.2	6.6
10.	Sowing to physiological maturity (PM)	134	128	122	113	124	7.9	6.3
11.	Sowing to harvesting	140	131	129	123	131	6.5	5.0
12.	Tillering stage (from 1st tiller initiation date to before 1st boot stage)	50	48	43	38	45	5.1	11.3
13.	Flowering stage (from 1st flowering date to before 1st dough date)	11	10	11	10	11	0.8	7.2
14.	Vegetative phase (1st emergence date to before 1st ear head emergence date)	79	75	71	67	73	4.8	6.6
15.	Reproductive phase (1st anthesis date to before 100% PM date)	43	41	38	33	39	4.2	10.8
16.	Ripening phase (1st dough to 100% PM date)	19	19	20	16	19	1.7	8.9
17.	Milking to dough (1st milking date to before 1st dough date)	13	12	7	7	10	2.9	29.0
18.	1st emergence to harvesting	135	126	123	116	125	7.5	6.0
19.	PM to harvesting (1st PM to harvesting date)	11	11	10	7	10	1.6	16.6

Results and Discussion

Effects of weather variables on the grain yield of wheat

The correlation coefficients between grain yield and various weather parameters and agrometeorological indices, observed during different growth phases, are given in Table 2. The duration required for the wheat crop to reach different growth stages is presented in Table 1. Identification of different growth phases and their durations is vital for optimizing dry matter allocation and accumulation in wheat plant organs, which in turn affects the crop's vulnerability to environmental stresses and external pressures (Sattar *et al*., 2023). The results indicated that during the 1st, 50%, and 100% emergence stages, the mean maximum and mean temperatures had a highly significant negative correlation, while the minimum temperature had a highly significant positive correlation, and the temperature range had a positive correlation at these three growth stages, as shown in Table 2. Specifically, during the 10%, 50%, and 100% emergence stage, sowing to physiological maturity (PM), sowing to harvesting, tillering, reproductive stage, ripening phase, milking to dough, first emergence to harvesting, and PM to harvesting, the maximum temperatures had a highly significant negative correlation. From sowing to PM, sowing to harvesting, tillering stage, ripening, first emergence to harvesting, and PM to harvesting, the mean temperature exhibited a highly significant negative correlation with grain yield. However, during the reproductive phase, maximum temperature, minimum temperature, and temperature range were found to be highly significant and negatively correlated to the yield. From first emergence to harvesting and PM to harvesting, mean temperature had a highly significant negative correlation with grain yield. Similarly, during the milking to dough phase, maximum, minimum, and mean temperature had a significant negative correlation, while temperature range showed a positive correlation with grain yield. Chakrabarti *et al*. (2021) found that higher temperature led to a reduction in leaf area and spikelet fertility, which consequently lowered wheat grain yield. A 2 ÚC rise in temperature led to a 15-17 percent reduction in the grain yield of both wheat and rice, with the decline being significantly greater in wheat at higher temperature (Hundal *et al*., 2004).

During the 1st, 50%, and 100% emergence stages, the mean bright sunshine hours showed a positive correlation with grain yield. However, during the sowing to tiller initiation phase and vegetative phase, a highly significant positive correlation of grain yield with bright sunshine was observed. Additionally, the bright sunshine hours at reproductive, vegetative, ripening, and PM to harvesting phase demonstrated a highly significant negative correlation, whereas during the sowing to anthesis phase, it had a significant positive correlation.

The mean morning relative humidity during the 1st, 50%, and 100% emergence stages and sowing to tiller initiation phases showed a highly significant negative correlation with grain yield (Table 2). Vashisth *et al*. (2022) at IARI, New Delhi, observed that at tillering and jointing stages, relative humidity within the canopy was lower and had a significant influence on the growth of the crop. From sowing to milking, sowing to dough, sowing to PM, sowing to harvesting, and tillering, flowering, and reproductive phases, it showed a highly significant positive correlation with the grain yield. Conversely, the mean afternoon relative humidity during the 1st, 50%, and 100% emergence stages and sowing to tiller initiation and sowing to booting phase also displayed a significant negative correlation with grain yield. However, during sowing to PM, sowing to harvesting, tillering stage, first emergence to harvesting, and PM to harvesting, grain yield showed a highly significant positive correlation with afternoon relative humidity. Relative humidity is a crucial factor for crop growth and yield, as increased relative humidity leads to reduced evapotranspiration from the field.

Effect of agrometeorological indices on grain yield of wheat

Agrometeorological indices such as GDD, HTU, and PTU during all the growth phases had a positive correlation with grain yield, except for PM to harvesting, where they had a negative relationship with the grain yield. For GDD, at tiller initiation, sowing to anthesis, sowing to milking, flowering stage, reproductive stage, milking to dough, and from

Table 2. Correlation coefficients between grain yield (kg ha^{-1}) of wheat and mean weather parameters and accumulated agrometeorological indices

S. No.	Phenophases	Weather parameters and agrometeorological indices													
		Tmax	Tmin	Tmean	Trange	BSH	RH I	RH II	Rainfall	Evapo-ration	ST I 5cm	ST II 15cm	GDD	HTU	PTU
1.	Sowing to 1st emergence date	-0.736**	0.897**	-0.760**	0.434	0.542	-0.851**	-0.572	0.122	0.856**	0.954**	0.951**	0.524	0.518	0.652*
2.	Sowing to 50% emergence date	-0.740**	0.766**	-0.759**	0.398	0.440	-0.906**	-0.532	-0.255	0.808**	0.952**	0.947**	0.543	0.569	0.553
3.	Sowing to 100% emergence date	-0.810**	0.853**	-0.851**	0.334	0.539	-0.805**	-0.487	-0.125	0.767**	0.933**	0.946**	0.458	0.447	0.563
4.	Sowing to tiller initiation	0.721**	0.601*	0.732**	0.758**	0.731**	-0.826**	-0.865**	-0.469	0.943**	0.925*	0.529	0.755**	0.547	0.555
5.	Sowing to boot stage	0.536	0.517	0.531	0.470	0.534	0.481	-0.068	-0.692*	-0.825**	-0.733**	0.339	0.551	0.657*	0.549
6.	Sowing to ear head stage	0.556	0.488	0.574	-0.077	0.492	0.478	0.264	-0.915**	-0.834**	-0.485	0.161	0.634*	0.751**	0.532
7.	Sowing to anthesis	-0.135	0.419	-0.269	-0.586*	0.637*	0.691*	0.458	-0.683*	-0.861**	-0.551	-0.346	0.735**	0.749**	0.533
8.	Sowing to milking	-0.475	-0.249	-0.364	-0.198	0.187	0.892**	0.553	0.376	-0.956**	-0.947**	0.484	0.724**	0.644*	0.522
9.	Sowing to dough	-0.516	0.528	-0.522	0.508	0.388	0.803**	0.538	0.000	-0.861**	-0.757**	-0.520	0.635*	0.643*	0.531
10.	Sowing to physio-logical maturity (PM)	-0.886**	-0.846**	-0.872**	-0.794**	0.076	0.937**	0.911**	0.000	-0.933**	-0.925**	-0.480	0.529	0.542	0.622*
11.	Sowing to harvesting	-0.894**	-0.852**	-0.879**	-0.920**	-0.467	0.893**	0.893**	0.000	-0.897**	-0.924**	-0.485	0.566	0.503	0.444
12.	Tillering stage (from 1st tiller initiation date to before 1st boot stage)	-0.734**	-0.762**	-0.741**	-0.717**	0.557	0.847**	0.731**	-0.468	-0.869**	-0.555	-0.776**	0.526	0.555	0.524
13.	Flowering stage (from 1st flowering date to before 1st dough date)	-0.525	-0.581*	-0.515	0.302	-0.659*	0.870**	0.173	0.699*	-0.796**	-0.099	-0.523	0.891**	0.855**	0.556
14.	Vegetative phase (1st emergence date to before 1st ear head emergence date)	0.167	0.398	0.272	-0.381	-0.912**	0.683*	0.486	-0.924**	-0.851**	-0.539	-0.261	0.444	0.557	0.542
15.	Reproductive phase (1st anthesis date to before 100% PM date)	-0.741**	-0.722**	-0.634*	-0.758**	-0.889**	0.738**	0.518	0.823**	-0.920**	0.325	-0.533	0.692**	0.602*	0.514
16.	Ripening phase (1st dough to 100% PM date)	-0.759**	-0.801**	-0.853**	-0.492	-0.729**	0.703*	0.623*	-0.255	-0.829**	0.524	-0.553	0.538	0.608*	0.537
17.	Milking to dough (1st milking date to before 1st dough date)	-0.606*	-0.633*	-0.701*	0.312	0.046	0.550	0.130	0.122	-0.466	0.060	-0.570	0.736**	0.777**	0.748**
18.	1st emergence to harvesting	-0.909**	-0.904**	-0.907**	-0.903**	-0.623*	0.905**	0.884**	0.000	-0.908**	-0.930**	-0.915**	0.863**	0.707*	0.638*
19.	PM to harvesting (1st PM to harvesting date)	-0.894**	-0.887**	-0.898**	-0.856**	-0.753**	0.775**	0.816**	-0.208	-0.527	-0.913**	-0.917**	-0.228	-0.509	-0.520

*Significant at 5% level **Significant at 1% level first emergence to harvesting exhibited a highly significant positive correlation with grain yield. For HTU, from sowing to ear head emergence, anthesis, flowering, and milking to dough exhibited a highly significant positive correlation with grain yield. In the case of PTU, at milking to dough, it had a highly significant positive correlation with grain yield.

Linear equations showing the relationship between grain yield and accumulated GDD, PTU, and HTU, bright sunshine hours (BSS) during the anthesis phase of wheat are illustrated in Fig.1. Similar results were recorded by Gupta *et al*. (2021).

Effects of weather variables on biomass production of wheat

Correlation coefficients between the above-ground biomass of wheat and various weather parameters and agrometeorological indices (GDD, HTU, and PTU) during different growth stages are presented in Table 3. In this study, weather variables and agrometeorological indices during different phenological stages were correlated with biomass and grain yield of the wheat crop.

The study on the effect of air temperature (Table 3) revealed that during the early stages of growth (1st, 50%, and 100% emergence), maximum, minimum, and mean temperatures showed a positive correlation with above-ground biomass. Particularly, the mean temperature from sowing to 50% of emergence exhibited a significant positive relationship with biomass yield. However, for minimum temperature, maximum temperature and mean temperature from sowing to milking, sowing to dough, sowing to physiological maturity, sowing to harvesting, tillering stage, flowering stage, reproductive, ripening, milking to dough, first emergence to harvesting and physiological maturity to harvesting registered a negative correlation with the above ground biomass, with significant correlation during ripening phase. However, positive correlation of biomass with minimum, maximum and mean temperature was observed during the vegetative stage. Temperature has a direct relation with biomass accumulation in crops. Chakrabarti *et al.* (2021) observed that high temperature contributed to a reduction in total wheat biomass due to reduction in leaf area.

Positive correlation of sunshine hours with biomass during most of the growth phases was observed. But significant positive correlations with biomass were observed during sowing to boot, sowing to ear head emergence, tillering, and vegetative stages. In the case of both morning and afternoon relative humidity (RH) during early stages like sowing to emergence and sowing to tiller initiation, a negative effect on biomass yield was noticed, while humidity during sowing to anthesis, sowing to milking, sowing to dough, sowing to physiological maturity, sowing to harvesting, and tillering (1^{st} tiller initiation date to before 1^{st} boot stage), flowering, reproductive, vegetative, ripening, milking to dough, first emergence to harvest and physiological maturity to harvesting stages tended to show positive correlations**.** RH during morning hours showed significant positive correlation during ripening phase, while RH during afternoon hours exhibited positive correlation during reproductive phase. Considering evaporation, biomass was significantly negatively correlated with evaporation rate during reproductive and ripening phases.

While evaluating the impact of soil temperature, a positive correlation was observed during 10%, 50%, 100% emergence and tiller initiation stages. On the other hand, negative correlations were found during the later stages of growth. Biomass yield was found to be positively correlated with soil temperature at 5 cm depth during sowing to emergence and sowing to 50% emergence stage. While Soil temperatures at 15 cm depth showed significant positive correlations during the 10%, 50%, 100% and tiller initiation stage.

Effect of agrometeorological indices on biomass production of wheat

GDD, HTU, and PTU demonstrated variable effects across different growth stages, overall showing a positive correlation during all the growth phases. These indices reflect the relationship between accumulated heat units and biomass production, which is highly influenced by atmospheric conditions like temperature and sunshine. The linear equations depicting the relationship between above ground biomass and accumulated GDD, PTU, and HTU during the anthesis stage of wheat are presented in Fig. 2.

Table 3. Correlation coefficients between biomass (g m^{-2}) of wheat and mean weather parameters, and accumulated agrometeorological indices

S. No.	Phenophases	Weather parameters and agrometeorological indices													
		Tmax	Tmin	Tmean	Trange	BSH	RH I	RH II	Rainfall	Evapo-ration	ST I 5cm	ST II 15cm	GDD	HTU	PTU
1.	Sowing to 1st emergence date	0.562	0.574	0.593*	0.213	0.298	-0.575	-0.283	-0.211	0.537	0.582*	0.605*	0.573	0.461	0.488
2.	Sowing to 50% emergence date	0.571	0.574	0.605*	0.179	0.270	-0.571	-0.270	-0.475	0.487	0.582*	0.611*	0.591*	0.519	0.587*
3.	Sowing to 100% emergence date	0.549	0.512	0.572	0.205	0.345	-0.513	-0.302	-0.171	0.498	0.550	0.582*	0.803**	0.637*	0.590*
4.	Sowing to tiller initiation	0.556	0.595*	0.582*	0.403	0.566	-0.564	-0.489	-0.044	0.572	0.564	0.594*	0.443	0.439	0.539
5.	Sowing to boot stage	0.590*	0.547	0.573	0.486	0.599*	0.134	-0.307	-0.358	-0.410	-0.319	0.383	0.444	0.523	0.543
6.	Sowing to ear head stage	0.549	0.542	0.547	0.140	0.588*	0.208	-0.059	-0.550	-0.428	-0.386	0.263	0.530	0.521	0.530
7.	Sowing to anthesis	0.195	0.372	0.280	-0.315	0.493	0.358	0.151	-0.513	-0.491	-0.401	-0.102	0.601*	0.610*	0.602*
8.	Sowing to milking	-0.110	-0.100	-0.050	-0.144	0.384	0.468	0.302	0.303	-0.563	-0.573	-0.298	0.540	0.530	0.539
9.	Sowing to dough	-0.253	-0.272	-0.263	0.416	0.405	0.419	0.189	0.000	-0.482	-0.568	-0.339	0.543	0.534	0.544
10.	Sowing to physiological maturity (PM)	-0.442	-0.430	-0.439	-0.375	0.255	0.523	0.467	0.000	-0.522	-0.532	-0.457	0.668*	0.660*	0.672*
11.	Sowing to harvesting	-0.466	-0.435	-0.454	-0.498	-0.094	0.473	0.448	0.000	-0.482	-0.523	-0.460	0.650*	0.658*	0.649*
12.	Tillering stage (from 1st tiller initiation date to before 1st boot stage)	-0.354	-0.403	-0.370	-0.332	0.584*	0.427	0.350	-0.106	-0.458	-0.468	-0.393	0.552	0.523	0.550
13.	Flowering stage (from 1st flowering date to before 1st dough date)	-0.554	-0.467	-0.515	0.016	-0.529	0.516	0.212	0.348	-0.533	-0.188	-0.533	0.497	0.574	0.600*
14.	Vegetative phase (1st emergence date to before 1st ear head emergence date)	0.299	0.393	0.344	-0.014	0.611*	0.297	0.126	-0.573	-0.434	-0.409	0.042	0.562	0.532	0.560
15.	Reproductive phase (1st anthesis date to before 100% PM date)	-0.558	-0.522	-0.542	-0.621*	-0.530	0.570	0.595*	0.395	-0.583*	0.112	-0.548	0.536	0.608*	0.541
16.	Ripening phase (1st dough to 100% PM date)	-0.589*	-0.611*	-0.608*	-0.123	-0.438	0.664*	0.561	-0.475	-0.620*	0.545	-0.638*	0.500	0.554	0.568
17.	Milking to dough (1st milking date to before 1st dough date)	-0.474	-0.538	-0.525	0.161	0.151	0.325	0.041	-0.211	-0.261	-0.264	-0.508	0.582*	0.657*	0.662*
18.	1st emergence to harvesting	-0.508	-0.501	-0.506	-0.537	-0.229	0.487	0.466	0.000	-0.498	-0.534	-0.499	0.636*	0.648*	0.633*
19.	PM to harvesting (1st PM to harvesting date)	-0.530	-0.472	-0.521	-0.580*	-0.351	0.396	0.470	0.171	-0.446	-0.553	-0.563	0.110	-0.097	-0.104

*Significant at 5% level **Significant at 1% level

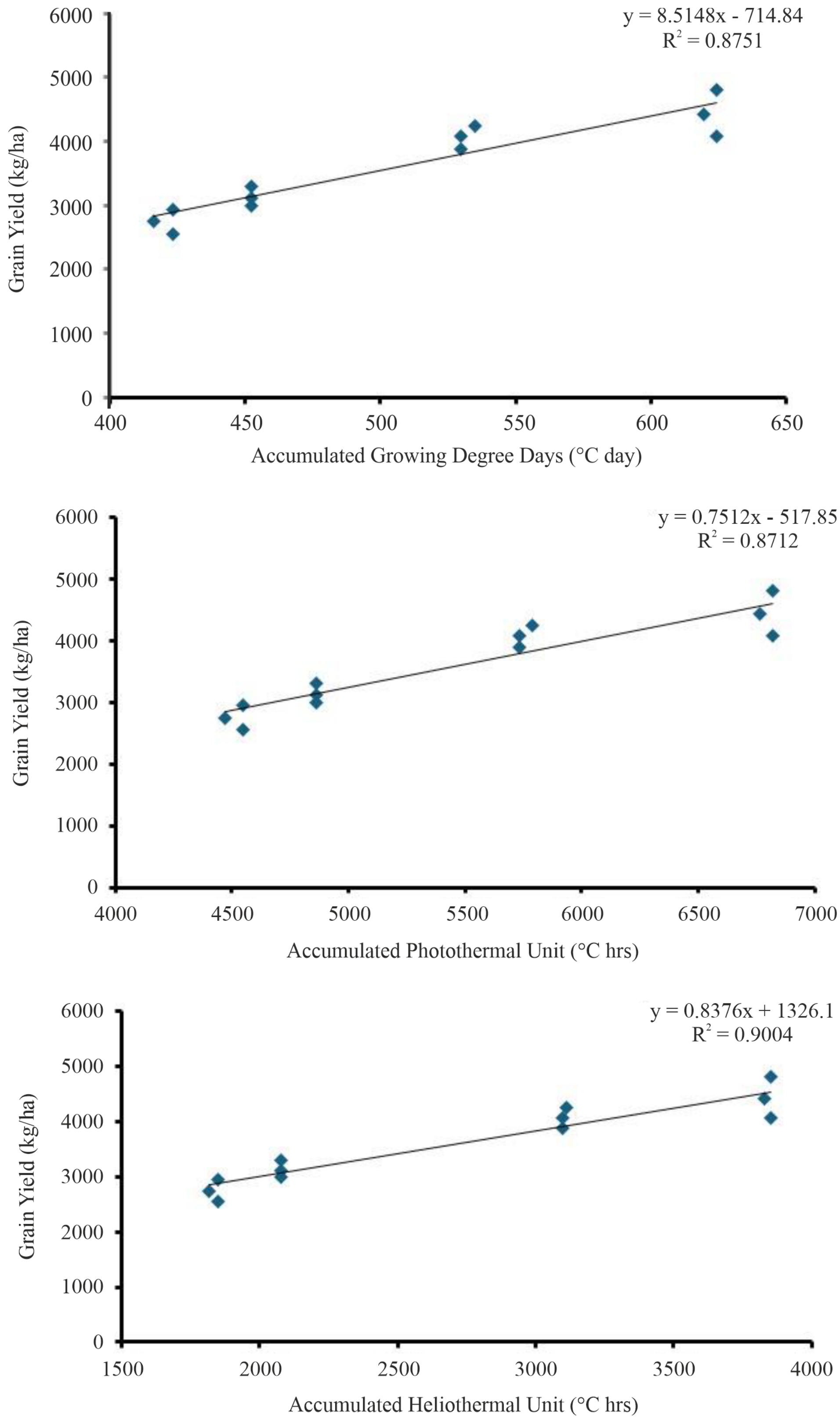

Fig. 1. Relationship between biomass and Accumulated Growing Degree Days (°C day), Accumulated Photothermal Unit (°C hrs) and Accumulated Helio thermal unit (°C hrs) during anthesis phase of wheat

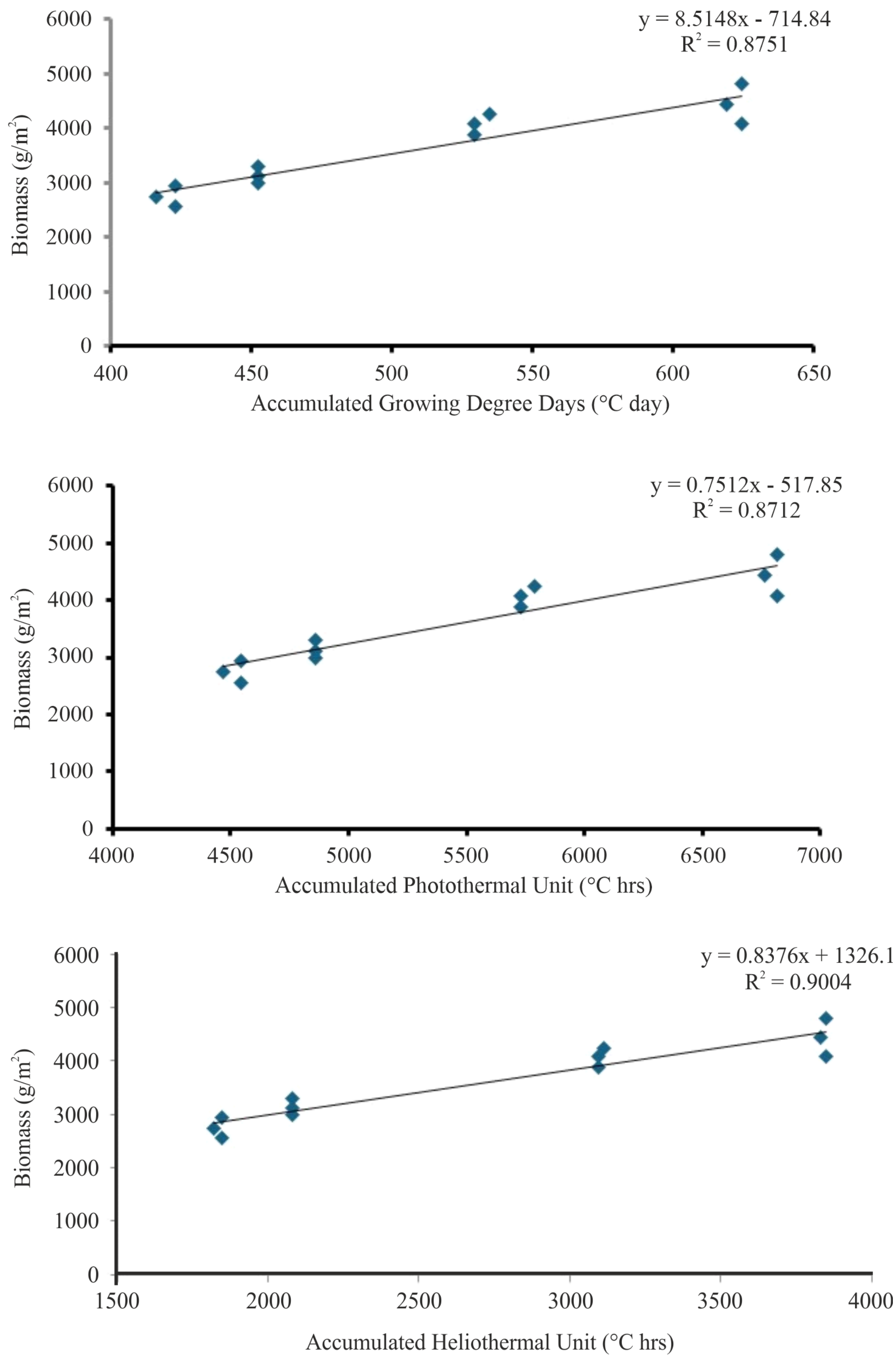

Fig. 2. Relationship between biomass and Accumulated Growing Degree Days (°C day), Accumulated Photothermal Unit (°C hrs) and Accumulated Helio thermal unit (°C hrs) during the anthesis phase of wheat

Conclusions

The study provided critical insights into the responses of wheat to the immediate resource environment. The growth and yield of wheat responded differentially at various phonological stages to weather variables and agrometeorological indices. Growing degree days (GDD), helio-thermal units (HTU), and photo-thermal units (PTU) exhibited a highly positive correlation with grain yield at the milking to dough stage, while at the physiological maturity to harvesting stage, a negative correlation of grain yield with GDD, HTU, and PTU was observed. For above-ground biomass, a negative correlation was noted with maximum, minimum, and mean temperatures at most of the growth stages. Bright sunshine hours had a significant positive correlation at the sowing to booting, sowing to ear-head, tillering stage, dough, and physiological maturity stages, but a positive correlation at the sowing to milking stage was observed. Relative humidity showed a positive correlation at various growth stages, while soil temperature at all depths exhibited a negative correlation at the anthesis stage. Biomass was found to be significantly influenced by GDD, HTU, and PTU at different growth stages.

References

Basu, S., Parya, M., Dutta, S.K., Maji, S., Jena, S., Nath, R., and Chakraborty, P.K. 2014. Effect of canopy temperature and stress degree day index on dry matter accumulation and grain yield of wheat (*Triticum aestivum* L.) sown at different sowing dates in the Indo-Gangetic plains of Eastern India. *Indian Journal of Agricultural Research*, **48**(3): 167-176.

Bist, H., Singh, D.K., Shaloo, Mishra, A.K., Sarangi, A., Prajapati, V.K., Singh, M. and Krishnan, P. 2019. Heat unit requirement of wheat under different thermal and moisture regimes. *Journal of Agrometeorology,* **21**(1): 36-41.

Bishnoi, O.P., Singh, R., and Kumar, V. 1995. Effect of temperature on phenology and productivity of wheat. *Journal of Agricultural Science*, **124**(3): 297-303.

Chakrabarti, B., Bhatia, A., Pramanik, P., Singh, S.D., Jatav, R.S., Das, N., Saha, R. and Kumar, V. 2021. Change in thermal requirements, growth and yield of wheat under the elevated temperature. *Indian Journal of Agricultural Sciences*, **91**(3): 435-439.

DES (Department of Economics and Statistics). 2022. https://www.ceicdata.com/ en/india/production-of-foodgrains-in-major-states-wheat/agricultural-production-wheat-bihar

Goutam, S., Sattar, A., Jha, R.K., Kumar, Ravi Ranjan., Singh, S.P., Nanda, G., Singh, G. and Pramanick, B. 2024. PAR interception pattern and radiation use efficiency in wheat. *Journal of Agricultural Physics*, **24**(1): 102-109.

Gupta, R., Singh, R. and Kumar, S. 2017. Influence of sowing dates on phenology, leaf area index, and yield of wheat. *Journal of Wheat Research*, **9**(1): 1-9.

Gupta, R., Singh, R., and Kumar, S. 2021. Effects of accumulated growing degree days, photothermal units, heat units, bright sunshine hours, and soil temperature on wheat grain yield. *Journal of Agrometeorology*, **23**(1): 34-41.

Hari Ram, Singh, G., Mavi, G.S. and Sahu, V.S. 2012. Accumulated heat unit requirement and yield of irrigated wheat wheat (*Tritium aestivum* L.) varieties under different crop growing environment in central Punjab. *Journal of Agrometeorology,* **14**(2): 147-153.

Hundal, S.S. and Kaur, P. 2004. Climatic change and its impact on crop productivity in Punjab, India. *Journal of Research, Punjab Agricultural University*, **41**(2): 108-116.

Liu, J., He, Q., Zhou, G., Song, Y., Guan, Y., Xiao, X., Sun, W., Shi, Y., Zhou, K., Zhou, S., Wu, Y., Ma, S., and Wang, R. 2023. Effects of sowing date variation on winter wheat yield: Conclusions for suitable sowing dates for high and stable yield. *Agronomy*, **13**(4): 991.

Narciso, G., Ragni, P. and Venturi, A. 1992. Agro-meteorological aspects of crops in Italy, Spain and Greece.

Pathania R., Prasad R., Rana Ranbir Singh., and Mishra S.K., 2019. Heat unit requirement and yield of wheat (*Triticum aestivum* L.) varieties under different growing environment in mid hill conditions of Himachal Pradesh, *Journal of Agrometeorology*, **21**(3): 282-287.

Premdeep, K., Kumar, A., Kumar, S., and Kumar, V. 2019. Constraints and opportunities for improving wheat productivity in India. *Journal of Wheat Research*, **11**(1): 1-9.

Sattar, A., Singh, G., Singh, S., Kumar, M., Kumar, P.V. and Bal, S.K. 2020. Evaluating temperature thresholds and optimizing sowing dates of wheat in Bihar. *Journal of Agrometeorology*, **22**(2): 158-164.

Sattar, A., Nanda, G., Singh, G., Jha, R.K. and Bal, S.K. 2023. Responses of phenology, yield attributes and yield of wheat to sowing environments and heat stress in Indo-Gangetic Plains, *Frontiers in Plant Science,* https://doi.org/10.3389/fpls.2023.1224334

Slafer, G.A. and Rawson, H.M. 1994. Sensitivity of wheat phasic development to temperature. *Crop Science*, **34**(1): 12-19.

Wheeler, T.R., *et al.* 1996. The effects of temperature and CO_2 on grain filling in wheat. *Journal of Experimental Botany*, **47**(9): 1431-1438.

Vashisth, A., Roy, D., Goyal, A. and Krishnan, P. 2022. Influence of meteorological parameters on wheat yield under different sowing conditions. *MAUSAM*, **73**(1): 161-172.

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