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CROP WEATHER RELATIONSHIP IN BARLEY

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SUMMARY

The phenological development of Barley is critical for optimizing growing strategies and varietal environmental influenced under variable growing environments climatic conditions. The experiment was carried out with split plot design in 2023-24 (*Rabi*/winter season). A field study during the 2023–24 crop season was evaluated the impact of different growing environments (with interval of time as popularly known as "sowing dates" sown crop which influenced by different prevailing environments and weather parameters, respectively) and varieties on the phenological stages of Barley. The main aim to study the effect of weather on phenological development and photosynthetic active radiation balance in relation to leaf area index and dry matter production in Barley. Evaluated the weather relationship under different growing environments was directly influenced the growth and development in Barley. Observations revealed distinct shifts in key growth stages including emergence, crown root initiation (CRI), tillering, jointing, booting, anthesis, milking, dough, and physiological maturity. The D_1 sowing treatment recorded the longest duration to maturity (135 days), while D_4 matured fastest (103 days). Among varieties, BH 902 exhibited extended durations across all phenophases, reaching physiological maturity at 120 days, whereas BH 393 matured quickest. PAR-Radiation absorption increased significantly from tillering to maturity. The highest PAR absorption was observed at the booting stage, corresponding to the maximum leaf area index (LAI). At this stage, treatment D1 recorded the highest absorption (95%), followed by D_2 (94%), D_3 (93%), and D_4 (92%). Observational analyzed results highlight the crop's vulnerability to wind speed, dewfall, and leaf wetness during critical phenological stages. Among the varieties, BH 902 and BH 885 showed the highest PAR absorption (94%), followed by BH 393 (93%), with BH 946 recording the lowest absorption (92%).

Key words: Barley phenology, growing environments, weather-relation, phenotypic variation (phenophases), physiological maturity, BH 902, BH 393

Barley (*Hordeum vulgare* L.) is a resilient cereal crop cultivated in diverse agro-climatic zones. However, its performance is significantly influenced by microclimatic factors, particularly during sensitive growth stages. This study documents the impact of wind speed, dewfall, foggy weather conditions (days) and irrigation on barley growth and development in Hisar, Haryana (AICRPAM, 2022). North West (NW) region of the country, Barley is predominantly cultivated as a Rabi season crop, sown between November and December. It is typically harvested from 2^{nd} fortnight of April to the first week of May, depending on the prevailing weather conditions during the reproductive stage (Chhabra *et al*., 2018). If the air temperature during reproductive phase exceeds to the normal range by ~2.8 to 3.2°C, it may induce forced maturity (reduced the number day in reproductive stage), thereby shortening the crop duration and leading to early maturity. Barley is an important cereal crop cultivated across diverse agro-ecological regions due to its adaptability and multipurpose utility. The timing of phenological events plays a pivotal role in maximizing yield and resource use efficiency. Phenology is influenced by genetic makeup, environmental cues, and agronomic practices such as sowing time. Understanding varietal and temporal differences in developmental stages is crucial under climate variability. Under this study assesses the weather based phenological behaviour of barley genotypes under varied growing environments (sowing dates) to identify optimal combinations for growing period.

Weather based relationship of Barley

A strong correlation between LAI and PAR absorption observed across all phenophases, indicated that the decrease in leaf area corresponds to a decrease in the ability of crop to absorb PAR (photosynthetically active radiation) for photosynthesis which could be determinantal to growth, stage and final yield of the Barely crop (Renu *et al.* 2023; Godara *et al.* 2024). Leaf area index (LAI) play an important role in understanding photosynthesis, radiation (solar light) interception, abruption, water and nutrient use with significant influenced to the crop growth. A better understanding of the relationships between crop development and environment is thus important (Singh et al., 2018). The yield and yield attribute as influenced by treatments. The growing environments and varieties showed the significant effect on Barley grain yield during 2022-23 (Bal *et al.*, 2023). Yield attributing characters and yield, spike weight (g), number of spikelet's/spikes, number of grains per spike, test weight (g), grain yield (q/ha), biological yield (q/ ha), and straw yield (q/ha), were found higher in 15th Nov growing environment due to higher leaf area index and thus early sown crop accumulated more dry matter (Renu *et al.*, 2024). The foggy weather is somehow advantage to the agriculture crop as the meet some requirement of irrigation (Anil *et al.*, 2015).

Spectral characteristics

The spectral composition of incoming solar radiation is also essential in determining plant growth and yield. Solar radiation in the range of 0.4 to 0.7 m, known as photosynthetically active radiation (PAR), is thus essential for photosynthesis and is the direct determining factor in plant growth (Durand *et al.*, 2021; Dagar and Kumar, 2024). Photosynthesis process is very crucial for physiological growth of Barley crop, determining the plant's productivity (Godara *et al.*, 2024). Negative relationship between BSS and Barley Straw yield. The excessive solar radiation lead to day temperature, during the reproductive and grain-filling stages will be accelerate senescence, reducing the duration of vegetative growth (day) and biomass accumulation (g/°Cday).

MATERIALS AND METHODS

Experimental site location at Department of Agricultural Meteorology, CCS HAU, Hisar. Treatments details: Factor A: 4 Sowing dates: D_1: 2nd Nov. 2023, D_2: 17th Nov. 2023, D_3: 2nd Dec. 2023 and D_4: 17th Dec. 2023. Factor B: 4 Cultivars were four university developed verities as V_1: BH 393, V_2: BH 902, V_3: BH 946 and V4: BH 885. The Spacing: Inter - row: 22.5 cm maintained, Net plot size: 5.0 m x 3.6 m, Gross plot size: 6.0m x 4.5m and with four replications. Experimental observations recorded: Different visual and instrument-based observation were carried out as Phenological observations (periodically), Micrometeorological observations, LAI, biomass and dry matter partitioning at different phenological stages and finely Yield attributes and yield at harvest.

Micrometeorological study over the Barley: Radiation Characteristics of Barley: A line quantum sensor was employed to measure the photosynthetically active radiation (PAR) in the 400–700 nm range, expressed Millimoles/meter square. These values were subsequently converted to Watt/ meter square by multiplying with a factor of 0.219. Measurements were taken at two canopy levels: above the crop canopy and at the ground surface. Radiation data were recorded during key phenological stages of barley as namely tillering, jointing, booting, anthesis, milking, and physiological maturity (PM), between 12:30 and 13:30 IST.

Dew amount: The dew fall amount was converted and considered as *i.e.* one millimeter (mm) of dew fall (night) = 1 liter of water per square meter added in the barley crop. Further water added (WA)= from the western disturbance rainfall water added m^{-2} by dew fall and foggy weather as fog in barley were considered as *i.e.* 1 mm of rainfall = 1 litre of water per square meter added through free natural commodity, through winter rainfall, through western disturbance (WD).

Different scale to use for measurement and analysis of dew, and fog data: 0=one hour at time condensation (before the reaching the minimum temperature period. 1= three hours of wetting leaf surface of Barley. 2= Six hours of wetting leaf surface. 3=Nine hours of wetting leaf surface. Thick Fog (den fog) =10-12 hours of wetting leaf surface barley. Moderate (medium) Fog=6-8 hours of wetting leaf surface. Light (thin) Fog=3-6 hours of wetting leaf surface. 0.4 mm of water added in the soil during thick fog condition per day was considered.

Phototemperature (during daylight hours *i.e.* typically from sunrise to sunset) and Nyctotemperature (Average temperature during night-time hours (typically from sunset to sunrise). Number of foggy (Anil *et al.*, 2015) and rainy days, mean intercepted photosynthetically active radiation (PAR) and grass minimum temperature (°C). Dewfall was measured at 5 cm, 25 cm, 50 cm, and 100 cm heights, with daily totals averaged weekly. Additionally, the Temperature-Humidity Index (THI), crucial during the reproductive stage of barley, and the Wind Chill Index (WCI), indicative of cold wave events or low air temperature, were computed as weekly averages.

Data (yield and yield attributes, weather-based product analysis) were analyzed by using OPSTAT software available (on campus users: http:// 192.168.2.174/opstat/default.asp) at CCS Haryana Agricultural University website (Sheoran *et al*., 1998). The results are presented at five per cent level of significance (p=0.05) for making comparison between the growing environments and varietal treatments.

RESULTS AND DISCUSSION

The phenological progression of barley was significantly affected by both sowing date and varietal differences. The D_1 treatment extended the crop cycle to 135 days, while D_4 shortened it to 103 days. Notably, D_4 treatment consistently led to quicker attainment of all phenophases from tillering onward. Among the genotypes, BH 902 took the longest duration across all stages CRI (26 days), tillering (40 days), jointing (67 days), booting (83 days), anthesis (93 days), milking (104 days), dough (111 days), and physiological maturity (120 days). In contrast, BH 393 achieved all phenological stages earlier than the other varieties, highlighting its potential for shorter growing seasons.

Prevailing weather condition under different growing environments i.e. D_1, D_2, D_3 and D_4

The daily weather parameters *viz* maximum (T_{max}) & minimum temperatures (T_{min}), wind speed (WS) and rainfall (mm) during the barley growing season starting from 1st Nov, 2023 with the sowing of first treatment (D_1) and up to 28th March 2024 *i.e.* physiological maturity of the last sowing (D_4) are presented in Fig. 1.0. The straight lines show the crop duration and coinciding stages with the weather situation. From figure (see red circle) we can conclude that at reproductive stage coincide with rainfall followed by high wind speed resulting in lodging of Barley which affected the grain yield. Moreover, during Jan-Mar 2024 there were 30 days with above normal (>2°C above normal) minimum temperature contributed to the reduced yield.

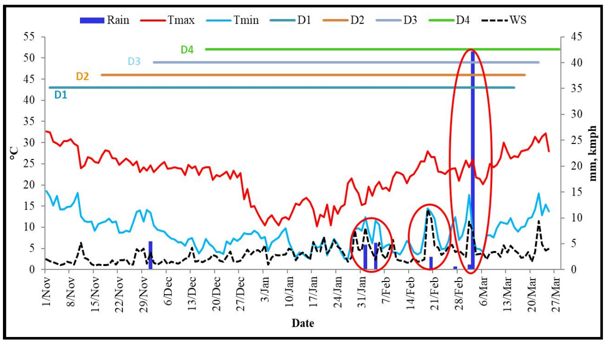

Fig. 1.0: Daily weather condition during barley crop season 2023-24.

Weather relation with Prevailing weather entities during the crop season

The barley crop is highly sensitive to wind speed, dewfall, and irrigation, particularly during the flag leaf to panicle initiation stage. Lodging was observed when the average wind speed exceeded 7.3 km/hr^{-1}. A single-day dewfall of 0.80 mm, recorded at both 50 cm and 100 cm canopy heights, initiated lodging that persisted up to the soft dough. One irrigation was applied in the Barley (under the semi-arid agro-climatic conditions of Hisar), natural free commodity as water added by the rainfall, dewfall and foggy weather condition was notice and analysed amount of water and a single irrigation applied (*i.e.* ~60–65 mm per hectare-flooded irrigation), it was sufficient to completed the barley crop's lifecycle, respective growing environment. During the crop period, an average of 2.0 to 2.8 days of wet western disturbances occurred (Table 1.0), primarily in January and February, contributing marginal rainfall that influenced the crop's as irrigation requirements (Table 1.0 and Fig. 1.0). Leaf wetness duration ranged from 2 to 12 hours, an average 6.0 hours respectively to the growing environments during December, January, February and 1st fortnight (FN) of March (Table 1.0). The optimal thermal regime from growing (grown) to the soft dough stage was characterized to varied by Maximum temperature (T_{max}): 18.5–24.0/ °C *i.e.* day time prevailed air temperature surround to the Barley crop, Minimum temperature (T_{min}): 5.1–8.0/ °C night time influenced air temperature and grass minimum temperature (G_{min}): 1.5–3.5/ °C, near the ground surface or grass surface temperature at early morning time was observed adjacent to the experimental field. WCI Range Observed: 9.5 to 13.2. in the Table 1.0, the WCI was analysed with range 9.5 to 13.2 (moderate range during the 48th to 13 SMWs), (WCI value analyzed in between 10–13 during vegetative stages which favored to promotes optimum development of Barley crop) which might be reflects the cooling effect of wind on ambient temperature, influencing crop microclimate. THI Range was analysed and its variation from 63 to 78 (48th to 13 SMWs), THI index combines air temperature and relative humidity to assess thermal stress on Barley crops (Table 1.0). the lower to moderate value of THI was analysed 53.63–72 (Table 1.0), which might be indicates optimal thermal comfort for barley crop during vegetative and early reproductive stages. The range were supported as efficient photosynthesis activities, nutrient uptake from soil (due less stress), and leaf expansion as leaf area incremental. The variation of grass minimum temperature -0.9 to 11.6 °C from 1st SMW to 13th SMWs, was observed variation from –0.9°C to 11.6°C reflects the dynamic thermal micro-environment of barley.

Phototemperature, an average of 19.9°C and a range from 12.1°C to 27.6°C, and the necto temperature, with an average of 12.5°C and a range from 7.0°C to 19.3°C, were analyzed during the growth period of barley from the initial sowing environment to the soft dough stage under Hisar, Haryana conditions (Table 1.0).

Fog and dew fall were observed during the crop cultivation from 48 to 13 SMWs in the barley crop. The 18.9 mm total dew amount was observed which act with create as the humid microclimate, reduced the transpiration rate (mm/night), wetting the root zone up to 6-8 cm (Table 1.0). Phenological Behaviour of Barley: Barley crop, growth and development, is distributed in different phenophases *viz.* emergence, crown root initiation (CRI), tillering, jointing, booting, anthesis, milking, dough and physiological maturity (PM). Different sowing dates and varieties have significant effect on phenology of barley crop during year 2023-24 (Table 2.0). The D_1 treatment took maximum days to reach at physiological maturity (135 days), followed by D_2 (123 days), D_3 (112 days) and D_4 (103 days). Significantly lower days were taken by D_4 to attain different phenophases from tillering.

Among barley varieties, BH 902 took significantly higher days for each phenological stage *i.e.* CRI (26 days), tillering (40 days), jointing (67 days), booting (83 days), anthesis (93 days), milking (104 days), dough (111 days) and physiological maturity (120 days). Whereas, BH 393 took lowest number of days to attain the respective phenological stages.

TABLE 1.0

Weekly weather-based entities during crop season (*Rabi* 2023-24) of Barley

SMW	LWH	PT	NT	FD	RD	IPAR	Gmin	DF	WA	THI	WCI
48	2	20.3	12.2	0.0	1	-	-	0.7	0.7	65.6	10.7
49	6	19.2	10.3	0.0	0	-	-	2.95	2.95	61.5	9.5
50	5	18.5	9.7	0.0	0	-	-	3	3	59.5	10.3
51	9	18.8	12.2	1.0	0	-	-	4.5	4.5	58.6	10.4
52	11	20.3	12.2	7.0	0	-	-	0	0	67.4	12.5
01	1	12.1	**7.0**	1.0	0	5.54	0.1	0	0	53.6	11.5
02	7	13.0	**8.5**	4.0	0	9.7	1.3	0	0	56.1	12.1
03	9	14.4	**7.2**	6.0	0	11.2	-0.9	0	0	54.9	11.6
04	8	16.2	10.3	5.0	0	11.3	3.6	0	0	59.1	11.8
05	3	17.0	10.1	3.0	2	12.9	2.3	0	0	60.1	12.9
06	12	21.3	13.3	1.0	0	14.4	6.4	1.6	1.6	63.7	12.1
07	9	20.8	11.8	6.0	0	17.2	4.5	0	0	62.4	11.1
08	5	23.8	15.3	2.0	0	20.0	8.3	0.65	0.65	67.5	11.2
09	3	21.4	14.3	0.0	1	22.0	10	1.9	1.9	59.6	10.0
10	3	23.9	15.3	1.0	0	46.7	8.4	1.5	1.5	67.9	10.3
11	2	27.6	19.3	0.0	0	57.0	11.6	1.25	1.25	72.0	11.2
12	1	23.7	17.7	0.0	0	55.5	11.2	0.85	0.85	69.6	13.2
13	0	25.8	18.8	0.0	0	59.5	10.3	0	0	70.7	13.1
Average (x)/sum (Σ)	x 5	19.9	x12.5	Σ37	Σ04	Σ343	x 5.9	Σ18.9		x62.7	x 11.4

Whereas, LWH: Average weekly leaf wetness hours (hr.), FD: Foggy days (no.), RD: Rainy days (no.), IPAR: Intercepted photosynthetic active radiation (MJt/m^2/day), Gmin: Grass minimum temperature (°C), DF: Dew fall (mm), WA (mm)=water added per square meter by dew fall in barley (i.e. 1 mm of rainfall=1 litre of water per square meter considered), PT: Phototemperature (°C), NT=Nyctotemperature (°C), THI/TCI: Temperature humidity index, WCI: Wind Chill Index (WCI) in Barley.

Plant height (cm): Plant height of barley crop increased with advancement of crop growth and development. Different sowing dates and varieties had significant effects on plant height of barley crop during year 2023-24 (Table 2.0). Significantly higher plant height was recorded under D_1 as compared subsequent sowing treatments at different phenological stages. The significantly lower plant height was recorded under late sown crop (D_4) over other dates of sowing. At physiological maturity, maximum plant height was recorded in D_1 (104.3 cm), followed by D_2 (101.4 cm), D3 (100.2 cm) and D_4 (98.1 cm). Among barley varieties, at each phenological stage, significantly taller plants were recorded of BH 902 (104.8 cm) as compared to other barley varieties followed by BH 946 (103.5 cm), BH 885 (100.0 cm) and BH 393 (95.6 cm).

Leaf area index (LAI): Leaf area of barley crop increased with advancement of crop growth and development, and reached at peak at booting stage and decreased there after (Table 4.0). This may be due to diversion of assimilates to reproductive part and no addition of new leaf after flag leaf stage. As the sowing of barley crop delayed, the LAI decrease gradually. Significantly higher LAI was recorded in D_1 as compared to other sowing dates at each phenophase of barley. Maximum LAI at booting stage was attained by barley crop in D_1 (6.88) followed by subsequent sowing dates *viz*. D_2 (6.37), D_3 (5.82) and D_4 (5.56). Among the varieties BH 902 recorded highest LAI (7.02) followed by BH 946 (6.39), BH 393 (5.98) and BH 885 (5.23).

Chlorophyll content index (CCI): The chlorophyll content in barley leaves peaked at the booting stage, aligning with the highest LAI. While sowing dates had limited influence on CCI overall, significant variations were observed at booting and anthesis. BH 393 exhibited superior chlorophyll retention potential, suggesting better photosynthetic efficiency at critical growth stages. Chlorophyll content index relative indicator of chlorophyll content of leaf was measured with chlorophyll meter. The CCI in barley crop increased gradually up to booting stage and then gradually decreased thereafter among all the sowing dates and varieties (Table 5.0). The dates of sowing didn't influence the CCI at different phenological stages of barley crop except at booting and anthesis. The highest CCI values were coincide with the highest LAI *i.e.* at booting stage. Among the different sowing environment, the highest CCI *i.e.* 45.23 was recorded in D_1 followed by D2 (36.56), D3 (32.10) and lowest in D_4 (31.13). At booting stage, BH 393 recorded significantly highest CCI values (40.75) and the lowest by BH 885 (27.40). The CCI of BH 902 was at par with BH 946.

Evaluated the PAR characteristics measurement on Barley: At the canopy surface, total incident PAR was measured, and reflected PAR was recorded from the same position in the reverse

TABLE 2.0
Effect of growing environments on phenology of barley varieties during 2023-24.

Treatment	Days taken								
	E	CRI	T	J	B	A	M	D	PM
Growing Environments (Sowing dates)									
D_1 (2 Nov 23)	7	24	43	66	82	92	109	124	135
D_2 (17 Nov 23)	7	25	38	68	81	93	103	111	123
D_3 (2 Dec 23)	10	25	37	66	82	93	101	105	112
D_4 (17 Dec 23)	11	24	36	62	79	89	95	96	103
SE (m)	0.10	0.12	0.19	0.18	0.30	0.32	0.50	0.30	0.19
CD (A) at 5%	0.38	0.42	0.68	0.64	1.06	1.14	1.76	1.06	0.67
Varieties									
V_1 (BH 393)	8	23	38	64	79	90	100	107	117
V_2 (BH 902)	9	26	40	67	83	93	104	111	120
V_3 (BH 946)	9	25	39	66	81	92	102	109	119
V_4 (BH 885)	9	24	38	65	80	91	99	108	118
SE(m)	0.17	0.21	0.20	0.19	0.31	0.33	0.56	0.31	0.22
CD (B) at 5%	0.28	0.61	0.59	0.55	0.90	0.97	1.64	0.90	0.65

E-emergence, CRI- crown root initiation, T- tillering, J- jointing, B- booting, A- anthesis, M- milking, D-dough, PM- physiological maturity.

TABLE 3.0
Effect of growing environments on plant height of barley varieties during 2023-24

Treatment	Plant height (cm)						
	CRI	Tillering	Jointing	Booting	Anthesis	Milking	PM
Growing Environments (Sowing dates)							
D_1 (2 Nov 23)	31.4	44.5	71.7	83.4	90.0	98.8	104.3
D_2 (17 Nov 23)	26.0	41.2	69.3	76.8	88.1	95.6	101.4
D_3 (2 Dec 23)	22.4	39.1	65.6	74.3	83.6	88.7	100.2
D_4 (17 Dec 23)	18.6	37.7	58.6	69.5	80.0	86.3	98.1
SE(m)	0.76	0.41	1.05	1.2	0.18	1.31	1.60
CD (A) at 5%	2.67	1.44	3.69	4.25	0.64	4.61	NS
Varieties							
V_1 (BH 393)	20.0	36.7	62.1	69.5	80.2	87.7	95.6
V_2 (BH 902)	29.7	45.9	70.7	80.0	92.0	96.6	104.8
V_3 (BH 946)	25.8	42.0	68.6	78.0	88.0	94.8	103.5
V_4 (BH 885)	22.8	37.7	63.7	76.5	81.6	90.3	100.0
SE(m)	0.60	0.68	1.15	1.04	0.36	0.70	1.11
CD (B) at 5%	1.76	1.99	3.39	3.05	1.05	2.03	3.24

TABLE 4.0
Effect of sowing dates on LAI of barley varieties during 2023-24

Treatment	LAI						
	CRI	T	J	B	A	M	D
Growing Environments (Sowing dates)							
D_1 (2 Nov 23)	0.86	3.57	5.19	6.88	5.86	3.49	2.56
D_2 (17 Nov 23)	0.85	3.17	4.99	6.37	4.91	3.02	2.05
D_3 (2 Dec 23)	0.76	2.88	4.37	5.82	4.31	3.00	1.90
D_4 (17 Dec 23)	0.70	2.65	3.97	5.56	4.17	2.92	1.76
SE(m)	0.02	0.06	0.07	0.08	0.07	0.01	0.06
CD (A) at 5%	0.06	0.21	0.23	0.29	0.26	0.05	0.21
Varieties							
V_1 (BH 393)	0.77	3.06	4.43	5.98	4.60	3.12	2.04
V_2 (BH 902)	0.85	3.55	5.65	7.02	5.49	3.37	2.21
V_3 (BH 946)	0.82	3.05	4.71	6.39	5.10	3.32	2.08
V_4 (BH 885)	0.72	2.60	3.72	5.23	4.07	2.61	1.94
SE(m)	0.02	0.05	0.07	0.11	0.08	0.18	0.05
CD (B) at 5%	0.04	0.16	0.20	0.32	0.24	0.54	0.14

CRI- crown root initiation, T- tillering, J- jointing, B- booting, A- anthesis, M- milking, D-dough.

direction. Transmitted PAR, representing the fraction of incident radiation passing through the canopy, was measured at ground level. Absorbed PAR was computed by subtracting both reflected and transmitted PAR from the total incident PAR.

Radiation characteristics of Barley: Line quantum sensor was used to measure the photo synthetically active radiation (PAR) in 400-700 nm range in micro mole/m^2/s (converted into watt/m^2 by multiply with factor 0.219) at two levels of crop canopy *i.e.* above the crop canopy and at the ground surface. The radiation observations were recorded at important stages of barley (tillering, jointing, booting, anthesis, milking and PM) during noon hours (1230-1330 hours IST). At canopy surface, total incoming/ incident PAR was observed and at same place (in reverse direction) reflected PAR was observed (Fig. 2.0).

Transmitted PAR was observed at ground surface which is fraction of incident PAR passes through crop canopy. Absorbed PAR was calculated by subtracting the reflected PAR and transmitted PAR from total incident/incoming PAR. The absorption of radiation increased considerably from tillering to

TABLE 5.0

Effect of growing environments on chlorophyll content index (CCI) of barley varieties during 2023-24

Treatment	CCI						
	CRI	T	J	B	A	M	D
Growing Environments (Sowing dates)							
D1 (2 Nov 23)	14.61	21.49	26.55	45.23	33.29	21.95	5.40
D2 (17 Nov 23)	12.96	19.25	22.70	36.56	30.78	20.74	4.05
D3 (2 Dec 23)	14.41	18.49	25.35	32.10	29.78	20.03	5.22
D4 (17 Dec 23)	14.69	19.54	21.44	31.13	28.49	18.05	5.12
SE(m)	0.61	0.81	1.42	0.47	0.73	2.12	0.33
CD (A) at 5%	NS	NS	NS	1.67	2.58	NS	NS
Varieties							
V1 (BH 393)	13.83	19.42	22.58	40.75	31.49	18.60	4.45
V2 (BH 902)	15.03	21.65	26.38	38.38	30.83	22.93	5.07
V3 (BH 946)	14.23	19.69	25.17	38.50	30.43	19.34	5.31
V4 (BH 885)	13.58	18.02	21.92	27.40	29.58	19.90	4.96
SE(m)	0.38	0.73	0.71	1.70	0.84	2.42	0.51
CD (B) at 5%	NS	2.15	2.08	4.99	NS	NS	NS

CRI- crown root initiation, T- tillering, J- jointing, B- booting, A- anthesis, M- milking and D- dough stage, NS-non-significant.

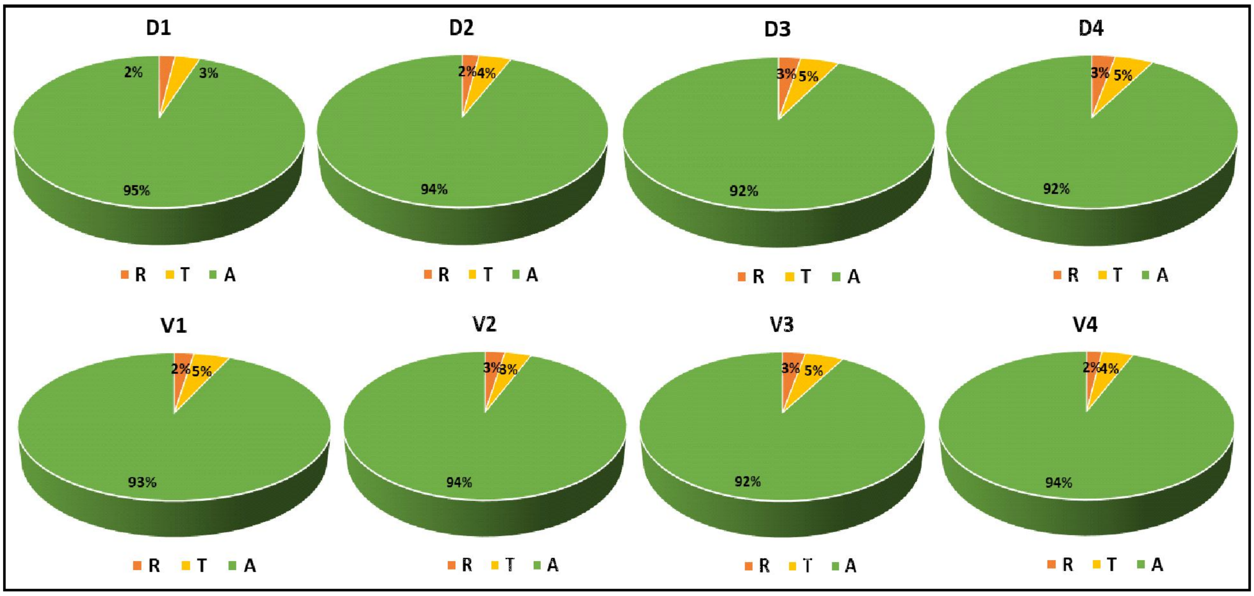

Fig. 2.0: PAR (%) behavior at maximum LAI (booting) stage in barley crop during 2023-24.

maturity. At maximum LAI stage i.e. booting, the absorption of PAR was maximum in D_1 (95%) followed by D_2 (94 %), D_3 (93%) and minimum in D_4 (92%) (Fig. 2.0). Among the verities BH 902 and BH 885 absorbed higher amount of PAR (94%) followed by BH 393 (93%) and lowest by BH 946 (92%).

Yield attributes and Yield: Effective tillers: Different sowing dates significantly influenced the effective tillers in barley during 2023-24 (Table 6.0). Significantly higher number of effective tillers (1157/ m^2) was recorded in D_1 as compared to subsequent sowing dates. Among varieties, BH 902 recorded significantly more effective tillers per unit area (1029/ m^2) than other varieties. Grains per spike and spike length: Different sowing dates did not have significant effect on grains per spike and spike length in barley. Highest grains per spike were found in D_2 (51.9) which was at par with D_3 (51.8). Among the varieties, maximum grains per spike were observed in BH 946 (58.1) and at par with BH 902 (58.0) followed by BH 393 (57.7). BH 885 recorded minimum grains per spike *i.e.* 26.3, as this variety is 2-row variety (Table 6.0). The spike length was more under D_3 sowing and BH 393 variety but the difference was non-significant.

Grain yield: Sowing dates showed significant effect on barley grain yield during 2023-24 (Table 6.0). The higher grain yield was recorded in D_1 (43.6 q/ha) as compared to other dates. Among the barley varieties, BH 393 recorded higher grain yield (41.7 q/ha) but difference among verities was non-significant as the crop experienced lodging. This was at par with BH 902 (40.6 q/ha). Lower grain yield was recorded in BH 885 (35.4 q/ha) as this is two-row variety and rest of varieties were six row varieties.

Evaluation of weather relationship (correlation): Correlation studies between weather parameters and grain yield of barley: The correlation studies between weather parameters and yield attributes and grain yield of barley are presented in Table 7.0. LAI had positive correlation with all the given weather parameters except for Tmax and Tmin but non-significant. CCI had negative correlation with T_{max}, T_{min}, BSS and rainfall. Grain yield was positively correlated with BSH and negatively with wind speed. The straw yield sowed reverse trend i.e. significantly and positively correlated with wind speed and negatively with sunshine hours. Higher BSS often leads to increased evapotranspiration (E_t), which was caused moisture stress, especially in semi-arid regions, Hisar when the prolong wet western disturbance. Bright sunshine might to be increase canopy temperature (T_c), may also reducing photosynthetic efficiency due to thermal stress (more bright hours) and stomatal closure.

Correlation studies between pooled of weather parameters: Correlation studies between pooled of weather parameters and yield of barley (2016-17 to 2023-24): Correlation studies between pooled of weather parameters and yield of barley (Table 8.0). The grain yield showed negative significant correlation with minimum temperature, wind speed and BSH, whereas, the straw yield showed negative significant correlation with morning relative humidity. Grain yield of barley exhibited a significant negative correlation with minimum temperature, wind speed, and bright sunshine hours, likely due to enhanced respiratory losses and reduced photosynthetic duration under such conditions. Straw yield was negatively affected by higher morning relative humidity, which may hinder transpiration efficiency and biomass accumulation in vegetative parts.

TABLE 7.0

Correlation coefficients of barley grain yield with weather parameters at different crop growth stages during 2023-24

Stage	Weather parameters						
	Tmax	Tmin	RHm	RHe	WS	BSS	RF
LAI	-0.04	-0.02	0.12	0.04	0.20	0.04	0.17
CCI	-0.16	-0.20	0.14	0.09	0.05	-0.04	-0.15
Grain Yield	-0.20	-0.81	-0.12	-0.72	-0.89	0.87	-0.82
Straw Yield	0.07	0.94	0.27	0.69	1.00*	-0.99*	0.76

Tmax- maximum temperature (°C), Tmin-minimum temperature (°C), RHm & RHe – morning and evening relative humidity (%), WS- wind speed (kmph), BSH- bright sunshine hours (hr.), RF- rainfall (mm), APAR- absorbed PAR (watt/m^2).

TABLE 6.0

Effect of growing environments on yield attributes and yield of barley varieties during 2023-24

Treatment	ET	GS	SL	TW	GY	SY	HI
Growing Environments (Sowing dates)							
D_1 (2 Nov 23)	1157	47.5	9.68	37.3	43.6	64.6	0.41
D_2 (17 Nov 23)	1033	51.9	9.71	38.3	39.6	66.3	0.37
D_3 (2 Dec 23)	887	51.8	10.31	33.5	40.8	72.1	0.37
D_4 (17 Dec 23)	713	48.9	9.96	32.4	32.4	76.0	0.32
SE(m)	30.9	1.50	0.19	1.31	1.90	3.80	0.02
CD (A) at 5%	43.8	NS	NS	4.54	6.60	NS	NS
Varieties							
V_1 (BH 393)	889	57.7	10.15	32.3	41.7	65.6	0.39
V_2 (BH 902)	1029	58.0	10.11	37.7	40.6	82.6	0.34
V_3 (BH 946)	947	58.1	9.81	34.5	38.7	61.2	0.39
V_4 (BH 885)	925	26.3	9.60	37.0	35.4	69.7	0.36
SE(m)	27.2	1.40	0.26	0.90	2.40	1.70	0.01
CD (B) at 5%	38.4	4.20	NS	2.79	NS	5.10	0.04

*ET – Effective tillers GS – Grains per spike (no.) SL – Spike length (cm) TW – Test weight (gram) GY – Grain Yield (q/ha) SY – Straw Yield (q/ha) HI – Harvest Index.

TABLE 8.0
Correlation of pooled of weather parameters and yield of barley (2016-17 to 2023-24)

Weather parameters	Grain yield	Straw yield
Maximum Temperature (T_{max})	-0.25	-0.04
Minimum Temperature (T_{min})	-0.64*	-0.35
Relative humidity morning (RH_m)	-0.31	-0.55*
Relative humidity evening (RH_e)	-0.21	-0.29
Wind Speed (WS)	-0.43*	-0.30
Bright sunshine hours (BSS)	-0.44*	-0.40
Rainfall (Rf)	-0.24	-0.15

*Values are significant at 0.05 probability level (N=28).

CONCLUSION

Based on the observations, it can be concluded that the absorption of PAR by barley increased progressively from the tillering stage to physiological maturity, with peak absorption occurring at the booting stage due to maximum leaf area development. Chlorophyll content in barley leaves peaked at the booting stage, aligning with maximum leaf area and photosynthetic efficiency. Growing environments had minimal impact overall, but BH 393 exhibited the highest CCI, indicating superior varietal performance. Among treatments, D_1 exhibited the highest radiation use efficiency (RUE), while varieties BH 902 and BH 885 demonstrated superior PAR absorption capacity, indicating their potential for enhanced productivity under semi-arid agro-climatic conditions. Barley cultivation in Hisar is highly sensitive to microclimatic fluctuations (within canopy microclimatic variation at diurnal basis), especially wind (<3.8 kmph) and dew-induced lodging (<0.17 mm/day). Findings emphasized the influence of growing environments and barley varietal influence with weather proofing in the development, aiding in cultivar performance, optimum growing windows in semi-arid region of Haryana.

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