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EFFECT OF GROWING ENVIRONMENTS AND VARIETIES ON GROWTH, DEVELOPMENT, YIELD AND AGROMETEOROLOGICAL INDICES IN BARLEY

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SUMMARY

The field study was conducted during *Rabi* 2019-20 at University Research farm of Department of Agricultural Meteorology, CCS HAU, Hisar. The two factor study comprised of four sowing dates as factor (A) namely (D1) -15th November, (D2) – 30th November, (D3) – 15th December and (D4) – 30th December, and four cultivars as factor (B) *viz*. (V1)- BH 393, (V2)-BH 902, (V3)- BH 946 and (V4)-BH 885. The experiment was laid out in factorial RBD design with three replications. The crop growth and phonological observations were found significantly highest in early crop sown on 1st fortnight of November (D1) that resulted in better overall growth and in terms of yield and yield contributing attributes and in variety BH 393(V1) that resulted in better overall grain and biological yield as compared to others. With respect to agrometeorological indices highest GDD, HTU, PTU were accumulated in crop sown on 2nd fortnight of December (D4) and in variety BH885 (V4) and highest TUE and RUE were found in crop sown on 1st fortnight of November (D1) and in variety highest TUE was found in BH 393 (V1) and highest RUE was found in BH 902 (V2) as compared to others.

Key words: Barley, GDD, RUE, PTU, growing environments and fortnight

Barley (*Hordeum vulgare* L.) is one of the most significant cereal grain crops, following rice, wheat, and maize. In India, barley is typically grown during the *Rabi* season, with sowing taking place from November to December and harvesting beginning in April to May. It is more productive under adverse environmental conditions than other cereals (Neelam *et al*., 2018). Barley is an excellent forage crop also due to its high nutritional value, adaptability, and short growing season. It provides energy and protein-rich feed suitable for cattle, sheep, and other ruminants. Barley can be utilized at various growth stages: grazed in the vegetative to boot stage or harvested for silage at the milk to dough stage. Proper seeding, fertilization, pest control, and water management are crucial for optimal yield and forage quality. Solar radiation is a valuable asset in crop productivity and is rarely a limiting factor in dry and semi-arid locations. Solar radiation interception and efficiency play an important role in dry matter formation. Aside from the use of fertilizers and pesticides and the genetic environment, grain production is still closely related to climate conditions because it is cultivated in open fields across large areas. Cereal grain production is determined by the crop's harvest index and radiation use efficiency (RUE). As a result, this study will look into the impacts of the growing environment, cultivars, and interactions on crop-weather linkages, radiation and energy components, barley growth, and yield in semi-arid conditions of Hisar.

MATERIALS AND METHODS

A field experiment was conducted in the University Research Farm, Department of Agricultural Meteorology, CCS HAU, Hisar during *rabi* season of 2019-2020 which is located at latitude 29°10'N, longitude 75°46'E and altitude of 215.2 m above mean sea level. The main characteristics of climate in Hisar are dryness, extreme of temperature and scanty rainfall with very hot summers and relatively cool winters. The experiment was comprised of four sowing dates as factor (A) namely (D1) -15th Nov., (D2) – 30th Nov., (D3) – 15th Dec. and (D4) – 30th Dec., comprising four different cultivars factor (B) *viz*. (V1)- BH 393, (V2) - BH 902, (V3) - BH 946 and (V4) - BH 885 in factorial RBD design with three replications. The inter row spacing was 22.5 cm and gross plot of size 4.0 m × 3.6 m and net plot of size 3.0 m× 2.6 m. Five randomly plants was selected, from destructive sampling were used to record the growth and development at CRI, Tillering, Jointing, Booting, Anthesis, Milking, Dough and Physiological maturity stages. Yield attributing characters were recorded at the time of crop maturity. The data was subjected to the Factorial RBD statistical analysis as per standard procedure. Agro-meteorological indices such as Growing degree days (GDD), Helio-thermal unit (HTU), Photo-thermal unit (PTU), were calculated for conforming period by using various weather parameters as below:

1. GDD (°C day) = $\sum_{i=1}^{n}(T_{\max}+T_{\min})/2-T_{base}$

Where, Tmax = Maximum Temperature (°C), Tmin = Minimum Temperature (°C) and T_{base} = Base Temperature

2. HTU = Σ (GDD x BSS)

Where, GDD = Growing degree days (°C days), BSS = Actual bright sunshine hours

3. PTU = Σ (GDD x N)

Where, GDD = Growing degree days (°C days) ,N = Maximum possible sunshine hours

4. TUE (g/m²/°C day) = $\frac{\text{DM (g/m}^2\text{) accumulate d}}{\text{Accumulate d heat units (°C days)}}$

5. RUE (g/MJ) = $\frac{\text{Biomass (g.m}^2\text{) accumulate d}}{\text{APAR (MJ/m}^2\text{) accumulate d}}$

RESULTS AND DISCUSSION

Among different growing environments, D1 took minimum time 7 days and D3 took maximum 13 days to complete emergence. The difference in days to emergence for November sowing might be due the higher temperature compared to December month (Munsif *et al.,* 2015). The days taken to attain physiological maturity stage were found higher in D1 and lower in late sown crop D4 (Table 1). A delayed sowing date caused a shortening of the growing season by 8-9 days, which was attributable to the shortening of all plant growth stages. The results are in conformity with the findings of (Kazimierz Noworolnik., 2012). Among varieties, the variety BH 393 took minimum time from emergence to physiological maturity which was about 122 days and the variety BH 885 took maximum 127 days because of the least effect of thermal stress as a result increased the days to reach physiological maturity during growth stages. (Khavse *et al.*, 2015)**.** The maximum plant height (119.37 cm) was observed at physiological maturity stage in D2 and minimum in late sown crop D4 (102.47 cm) due to the fact that vegetative phase of crop growth coincided with the low temperature, which reduces the growth of the plant by affecting its various metabolic processes (Singh et al., 2018). Among varieties, variety BH 902 was attained maximum plant height (120.27 cm), whereas, variety BH 393 was attained minimum plant height (103.44 cm) at physiological maturity due to variation in genetic framework of varieties (Table 1). The leaf area index at different growth intervals was recorded slightly higher in D1. The LAI was significantly higher from CRI to Booting stage and then decreased till physiological maturity because of extended vegetative phase causes more addition of foliage to the crop. The lower LAI in D4 because of crop faced higher temperature under late sowing causes reduction in crop duration and leads to forced maturity. Similar types of findings were supported by (Poudyal *et al.,* 2018; Singh & Yadav*,* 2019). Among varieties, BH 393 attained maximum LAI whereas, variety BH 885 attained lower LAI from CRI to Booting stage and which then further decreased upto physiological maturity. Chlorophyll content in barley increased progressively upto booting stage and then decreased at crop maturity phase. Maximum chlorophyll content was reported at Booting stage in D2 and minimum in D4. Among varieties, maximum chlorophyll content at booting stage was observed in variety BH 393 and minimum in variety BH 885. The dry matter accumulation per square meter increased from CRI stage to physiological maturity among varying growing environments and varying varieties at all growth stages followed the sigmoid pattern of growth curve. Among the varying growing environments D1 accumulated highest dry matter and D4 accumulated lower dry matter due to shortening of growing season in late sown crop. Data pertaining to dry matter accumulation showed that D2 and D3 has accumulated statistically similar dry matter at all crop growth stages and were better than D4 sown crop (Singh *et al.,*2018). The total dry matter accumulation was higher in variety BH 902 and was lower in variety BH 885 from CRI stage to physiological maturity primarily because of variety BH 902 attained abundant tillering and higher

TABLE 1
Effect of different date of sowing and different varieties on growth and development of barley under different growing environments

Treatments	Emergence (days)	PM (days)	Plant height (cm)	Max. LAI	Max. CCI	Total dry matter accumulated (g/m^2)
Date of sowing (A)						
D1 (15th Nov.)	7	134	114.5	5.47	32.24	1435
D2 (30th Nov.)	8	132	119.4	4.99	46.48	1277
D3 (15th Dec.)	13	121	112.3	4.47	37.04	1206
D4 (30th Dec.)	11	113	102.5	4.23	31.18	1043
SE(m)	0.34	0.58	1.1	0.22	1.60	36.7
CD at 5%	0.97	1.69	3.2	0.34	4.65	106.4
Varieties (B)						
V1: BH393	9	122	103.4	5.35	41.69	1266
V2: BH902	10	126	120.3	5.01	39.06	1299
V3: BH946	10	125	114.1	4.68	39.05	1218
V4: BH885	11	127	110.5	4.12	27.14	1178
SE(m)	0.34	0.58	1.1	0.22	1.60	36.7
CD at 5%	0.97	1.69	3.2	0.34	4.65	106

plant height throughout the season which leads to more biomass production from tillering stage to physiological maturity.

Yield attributes and yield

Yield of any crop species depends upon the source-sink relationship and is the collective function of various growth parameters and yield attributing characters as shown in Table 2. Among the yield attributing characters and yield, spike weight (g), number of spikelets/spike, 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 D_1 under varying growing environments due to higher leaf area index and thus early sown crop accumulated more dry matter as compared to others. Harvest index varied unsystematically with varying dates of sowing. Among varying growing environments, D1 observed higher grain (48.96 qha^{-1}) and biological yields (143.51 qha^{-1}) and were lowest in D4 due to shorter growing period reduced the rate of floral development or higher temperature during milking stage reduced the kernel weight and hence resulted in lower grain yield . The results were in conformity with the findings of Poudyal *et al.,* 2019; Chaudhary *et al.,*2017; Vaezi *et*

TABLE 2
Effect of different date of sowing and different varieties on yield and yield components in barley under different growing environments

Treatments	Spike length (cm)	Awn length (cm)	Spikelets/ spike	Grains/ spike	Spike weight (g)	Test weight (g)	Grain Yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
Date of sowing (A)									
D1 (15th Nov.)	16.5	8.3	45	44	2.85	42.94	48.96	94.55	33.93
D2 (30th Nov.)	17.2	9.1	44	42	2.60	40.62	43.99	83.76	34.36
D3 (15th Dec.)	17.7	9.9	42	40	2.45	39.60	48.40	72.27	40.20
D4 (30th Dec.)	17.6	10.0	42	41	2.28	41.45	43.18	61.17	41.71
SE(m)	0.21	0.15	0.88	0.79	0.06	0.88	2.91	2.99	1.98
CD at 5%	0.61	0.43	2.56	2.29	0.15	NS	NS	8.68	5.73
Varieties (B)									
V1: BH393	17.2	10.1	47	45	2.62	37.89	48.29	81.66	37.26
V2: BH902	18.7	10.6	52	50	3.51	43.18	41.91	84.73	33.09
V3: BH946	15.8	9.03	48	47	2.64	40.06	47.63	74.17	39.62
V4: BH885	17.3	10.4	25	25	1.41	43.48	46.69	71.19	40.23
SE(m)	0.21	0.15	0.88	0.79	0.06	0.88	2.91	2.99	1.98
CD at 5%	0.61	0.43	2.56	2.29	0.15	2.55	NS	8.68	NS

*al.,*2010; Singh *et al.,*2019.Among varieties, grain yield (q/ha), biological yield (q/ha) and straw yield (q/ha) were highest in variety BH 393 while lowest in variety BH 885. The highest grain and biological (48.29 and 129.95 q/ha) were observed in variety BH 393. The reason was being better partitioning of biomass to economic sink and higher biomass production and higher grains/spike in variety BH 393 resulted to more grain and biological yield as compared to variety BH 885.

Agrometeorological indices

The maximum GDD values were recorded at physiological maturity under all sowing dates and varieties (Table 3). Among the growing environment, D1 utilized the highest GDD value from emergence (118.1 °C days) to jointing stage (541.9 ° C days) and from anthesis to maturity stage it utilized the lowest GDD value and D4 utilized the highest GDD value. The reason of being higher GDD (1355° C days)in late sown crop (D4) at reproductive stages was that late planted crop quickly come to flowering and maturity within short time span due to high temperature after January month so the accumulated GDD were also moderately higher due to higher temperature. Among varieties, the maximum value of GDD at physiological maturity stage of different variety was higher in BH 885 and lower in BH 393 .The maximum HTU values were recorded at physiological maturity under all sowing dates and varieties, D4 utilized the highest HTU value from Jointing to physiological maturity and lowest in D1. Among varieties, variety BH 885(7987 °C day hours) was accumulated higher HTU at all growth stages and and lowest in variety BH 393(7309 °C day hours) at all growth stages. The maximum PTU values were recorded at physiological maturity in D4 (16016°C day hours) and lowest in D1 (14324°C day hours) and highest in variety BH 885 (15435 °C day hours) and lowest in variety BH 393(14235 °C day hours). The reason of being highest accumulated GDD, HTU and PTU in the variety BH 885 that it took maximum time and lowest in variety BH 393 that it took minimum time to attain phenological stages. TUE and RUE (g/MJ) went on increasing from CRI to PM in all the varying growing environments and in all the varieties (Kaur *et al.,* 2016).

The continuous increase in biomass up to the physiological maturity stage resulted in increased TUE and RUE at successive growth stages Among varying growing environments, highest TUE were found in D1 (1.128 g/m^2/°C) and lowest was in D4 (0.771 g/m^2/°C) due to proportionate increase in dry matter accumulation/ heat unit absorbed. With delay in crop sowing, thermal use efficiency was decreased. Higher thermal use efficiency in timely sowing could be attributed to the highest grain yield. The results were in conformity with the findings of Kumar and Kumar, 2014; Prajapat and Saxena, 2018). Among varieties, maximum TUE was observed in variety BH 393(1.027 g/m^2/°C) and minimum in variety BH 885(0.888 g/m^2/°C. Efficiency of conversion of radiation into dry matter depends upon plant traits and environmental conditions. Among varying growing environments, highest RUE were found in D1 (6.88 g/MJ) and lowest in D4 (4.13 g/MJ). The reduction in RUE in late sown

TABLE 3

Effect of different date of sowing and different varieties on agro-meteorological indices of barley at physiological maturity stage under different growing environments

Treatments	GDD (°C day)	HTU (°C day hours)	PTU (°C day hours)	TUE (g/m2°C day)	RUE (g MJ-1)
Date of sowing (A)					
D1 (15th Nov.)	1277	6708	14324	1.13	6.88
D2 (30th Nov.)	1292	7573	14830	0.99	5.72
D3 (15th Dec.)	1243	7606	14479	0.97	5.13
D4 (30th Dec.)	1355	8893	16016	0.77	4.13
SE(m)	10.9	75.9	136	0.03	0.16
CD at 5%	31.7	220	394	0.09	0.47
Varieties (B)					
V1: BH393	1237	7309	14235	1.03	5.65
V2: BH902	1307	7803	15103	0.99	5.72
V3: BH946	1289	7680	14875	0.95	5.37
V4: BH885	1334	7987	15435	0.88	5.13
SE(m)	10.9	75.9	136	0.03	0.16
CD at 5%	31.7	220	394	0.09	0.47

crops was due to shortening of vegetative and reproductive growth stages as affected by high temperature stress in the late sown crops at reproductive stage (Fayed *et al.,* 2015). Among varieties, maximum RUE was observed in variety BH 902(5.714 g/MJ) and minimum in variety BH 885(5.131 g/MJ). The lower value of TUE and RUE in the variety BH 885 was due to this variety accumulated lower biomass yield and has lower photosynthetic area.

CONCLUSION

The crop growth and phenological observations were found significantly highest in early crop sown on 1st fortnight of November (D1) and in variety BH 902(V2) that resulted in better overall growth as compared to others. With respect to yield and yield contributing attributes crop sown on 1st fortnight of November (D1) and varietal highest in BH 393 that resulted in better overall grain and biological yield as compared to others. With respect to agrometeorological indices highest GDD, HTU, PTU were accumulated in crop sown on 2nd fortnight of December (D4) and in variety BH885 (V4) and highest TUE and RUE were found in crop son on 1st fortnight of November (D1) and in variety highest TUE was found in BH 393 (V1) and highest RUE was found in BH 902 (V2) as compared to others.

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