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Short Communication

Radiation interception, growth dynamics and agroclimatic indices of wheat under different sowing dates

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The growth and development of a crop are dependent on the ability of the canopy to intercept incoming radiation. The fraction of the incoming photosynthetically active radiation (PAR) that is absorbed by the canopy mainly depends on the LAI and crop geometry. Biomass production in plants depends upon the quantity of absorbed photosynthetically active radiation by leaves and gradually increases with the advancement of the phenological stages. Wheat is the second major staple food crop of India and covers approximately 30.6 million ha area with 98.5 million tons of wheat production in India (FAO 2017). The low productivity of wheat is mainly attributed to delay sowing, improper selection of varieties, poor irrigation facilities, and adverse weather conditions. Temperature, humidity, and radiation are major meteorological parameters that influence different phenological stages of any crop. High-temperature stress at 35°C from 10 days after anthesis to maturity reduced grain yield by 78%, grain number by 63%, and grain weight by 29%. Wheat growth and development were aided by below-average maximum and minimum temperatures (26.9°C and 11.1°C, respectively), above-average sunshine hours, and low rainfall (110 mm) (Dhaliwal *et al*., 2006). Phenological development from sowing to physiological maturity is related to the accumulation of heat. The different phenophases of a crop are predicted with the help of different agroclimatic indices. These were used to describe the changes in phenological behavior, growth parameters, and maturity of the crop, and their value varied in the crop from variety to variety. Keeping this in view, the present study was conducted to determine the radiation interception, growth dynamics, and agroclimatic indices of wheat under different sowing dates.

The field experiments were carried out at the Research Farm of with Punjab Agricultural University, Ludhiana during two consecutive *rabi* seasons of 2017-18 and 2018-19. The experiment was laid out in randomized complete block design with three wheat varieties (PBW-725, PBW-677 and HD 3086) sown on three different sowing dates (25th October, 15th November and 5th December) with three replications.

The growing degree days (GDD), helio-thermal units (HTU), photo-thermal units (PTU) and pheno-thermal index (PTI) were calculated following Nuttonson (1955). Pheno-thermal index (PTI) was calculated as:

$$\text{Phenothermal index} = \frac{\text{GDD between the two phenological stages}}{\text{Number of days taken between two phenophases}}$$

The PAR interception was measured at different phenological stages with the help of a Line Quantum Sensor (Model LI-190 SB) and output of Quantum Sensor was recorded with a digital multi-voltmeter and was calculated by using the following formula;

$$\text{PAR interception (\%)} = \frac{\text{PAR (I)-[PAR (T)+PAR (R)]}}{\text{PAR (I)}} X100$$

PAR (I) –PAR incoming above the canopy, PAR (T) –PAR transmitted to the ground, and PAR (R) –PAR reflected from the canopy

Radiation use efficiency can be termed as the relationship between the accumulations of biomass relative to the light intercepted by the crop.

$$RUE = \frac{\text{Ws}}{\text{IPAR}}$$

Ws: Total accumulated biomass, and IPAR: Intercepted photosynthetically active radiation

The linear relationship was developed between PAR interception and dry matter accumulation as well as leaf area index of crop recorded at 15 days interval.

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Table 1: Effect of sowing dates and varieties on accumulated growing degree days (AGDD) and helio-thermal units (AHTU) of wheat

Treatments	CRI	Tillering	Booting	heading	Anthesis	Milking	Physiological maturity
Dates of sowing	**Growing degree days (ºC day)**						
October 25	351.5	612.5	975.3	1083.4	1220.4	1400.6	1702.5
November 15	270.2	459.8	819.9	937.2	1107.9	1350.7	1665.5
December 5	198.7	370.4	757.5	896.5	1099.9	1341.4	1627.1
S.Em±	4.12	4.53	4.45	5.35	2.13	1.36	2.56
CD (p=0.05)	11.9	12.9	12.8	15.3	6.1	3.9	7.3
Varieties							
PBW-725	268.5	477.1	841.4	968.5	1129.3	1345.5	1640.7
PBW-677	279.6	483.6	856.3	981.4	1157.4	1383.2	1685.8
HD-3086	272.1	481.9	855.1	967.1	1141.5	1363.9	1668.6
S.Em±	4.12	4.53	4.45	5.35	2.13	1.36	2.56
CD (p=0.05)	NS	NS	12.8	15.3	6.1	3.9	7.3
Dates of sowing	**Helio-thermal units (ºC day hours)**						
October 25	1457.3	2858.7	4772.1	5354.8	6152.8	7519.2	10105.4
November 15	1263.1	2791.0	4676.2	5832.8	6708.7	8836.5	11483.2
December 5	1110.3	1882.9	4308.6	5987.0	7204.8	9415.6	11567.2
S.Em±	45.1	115.3	126.3	74.2	88.8	90.7	42.7
CD (p=0.05)	129.4	330.7	362.3	212.8	254.9	260.2	122.4
Varieties							
PBW-725	1244.4	2498.8	4518.5	5720.2	6586.8	8449.8	10863.2
PBW-677	1309.4	2515.3	4632.2	5799.4	6800.9	8729.6	11206.2
HD-3086	1276.8	2518.6	4606.2	5654.9	6678.5	8592.0	11086.2
S.Em±	45.1	115.3	126.3	74.2	88.8	90.7	42.7
CD (p=0.05)	NS	NS	NS	NS	NS	NS	122.4

Heat units accumulated by wheat varieties

The heat units accumulated by the wheat crop to attain physiological maturity under the 25th October, 15th November, and 5th December sowing were 1702.5, 1665.5, and 1627.1 (°C day) accumulated higher GDD under early sown crop than late sown crop on a pooled basis (Table 1). Variety PBW 677 accumulated the maximum number of growing degree days because of the genetic behaviour of each variety. Kaur *et al.* (2016) also concluded that the heat units accumulated were higher for early sowing (30th October) than for delayed sowing (30th November) due to the longer period of all the phenological stages. Mehta and Dhaliwal (2020) also depicted that heat use efficiency was higher in 25th October sown crop than delayed sowing.

At Ludhiana, the highest helio-thermal units were consumed by the crop sown on the 5th December (11567.2 °C day hours). The lowest HTU (10105.4 °C day hours) was observed during the reproductive stages of the 25th October sown crop (Table 1). The number of days taken from sowing to physiological maturity was higher under early sown crop (25th October), but due to shorter days and foggy weather conditions during flowering accumulated less number of maximum possible sunshine hours. The flowering gets started during the 2nd fortnight of January as compared to the late sown crops, in which the flowering stage was started during the 2nd fortnight of February to 1st fortnight of March. According to Ram and Gupta (2016) the maximum accumulation of HTU in late-sown crop at earing and maturity stage may increase the crop's thermo-sensitivity. This would cause ovary abortion and accelerate senescence in addition to reducing the availability of current photo-assimilates for developing grain and reducing the yield of the crop.

The photo-thermal units accumulated by the wheat crop to attain maturity under the 25th October, 15th November, and 5th December sowing were 18415.0, 18355.7, and 18263.6 (°C day hours) on a pooled basis at Ludhiana as depicted in (Table 2). The photo-thermal units accumulated were higher 18581.6 (°C day hours) in variety PBW 677 under different sowing dates. The results were similar with the findings of Kaur *et al.* (2016) depicted that maximum accumulation of PTU under early sowing may be because the crop took maximum calendar days which significantly reduced under late sowing. Under different sowing dates, *viz.,* 25th October, 15th November, and 5th December, pheno-thermal index (PTI) values attained by physiological maturity were 15.4, 20.5, and 21.5 as depicted in (Table 2). Ram and Gupta (2016) also explained that higher values of PTI under delayed sowing further confirmed acceleration in phenological stages during crop growth.

Table 2: Effect of sowing dates and varieties on accumulated photo-thermal units (APTU) and Pheno-thermal index (PTI) of wheat

Treatments	CRI	Tillering	Booting	heading	Anthesis	Milking	Physiological maturity
Dates of sowing				**Photo-thermal units (ºC day hours)**			
October 25	3683.7	6365.6	10148.9	11258.4	12757.5	14774.5	18415.0
November 15	2717.9	4732.6	8431.9	9744.7	11876.9	14664.6	18355.7
December 5	2049.3	3799.1	7977.9	9517.9	11668.3	14609.5	18263.6
S.Em±	43.1	47.1	42.9	47.4	39.5	35.0	36.5
CD (p=0.05)	123.8	135.0	123.1	135.9	113.3	100.5	104.8
Varieties							
PBW-725	2764.7	4925.3	8753.3	10132.8	11965.1	14510.0	18043.9
PBW-677	2882.5	4995.6	8910.1	10265.9	12243.7	14851.3	18581.6
HD-3086	2803.6	4976.2	8895.3	10122.7	12093.8	14687.1	18408.8
S.Em±	43.1	47.1	42.9	47.4	39.5	35.0	36.5
CD (p=0.05)	NS	NS	123.1	NS	113.3	100.5	104.8
Dates of sowing				**Pheno-thermal index**			
October 25	14.5	11.8	8.2	7.8	10.0	11.6	15.4
November 15	11.4	8.2	8.5	10.9	12.4	15.8	20.5
December 5	7.8	7.4	11.9	13.0	16.2	19.8	21.5
S.Em±	0.22	0.18	0.19	0.16	0.24	0.34	0.15
CD (p=0.05)	0.64	0.51	0.55	0.45	0.70	0.99	0.42
Varieties							
PBW-725	11.4	9.13	9.4	10.5	12.6	15.7	18.8
PBW-677	11.1	9.10	9.6	10.7	12.9	16.2	19.4
HD-3086	11.3	9.12	9.5	10.6	13.1	15.4	19.2
S.Em±	0.22	0.18	0.19	0.16	0.24	0.34	0.15
CD (p=0.05)	NS	NS	NS	NS	NS	NS	0.42

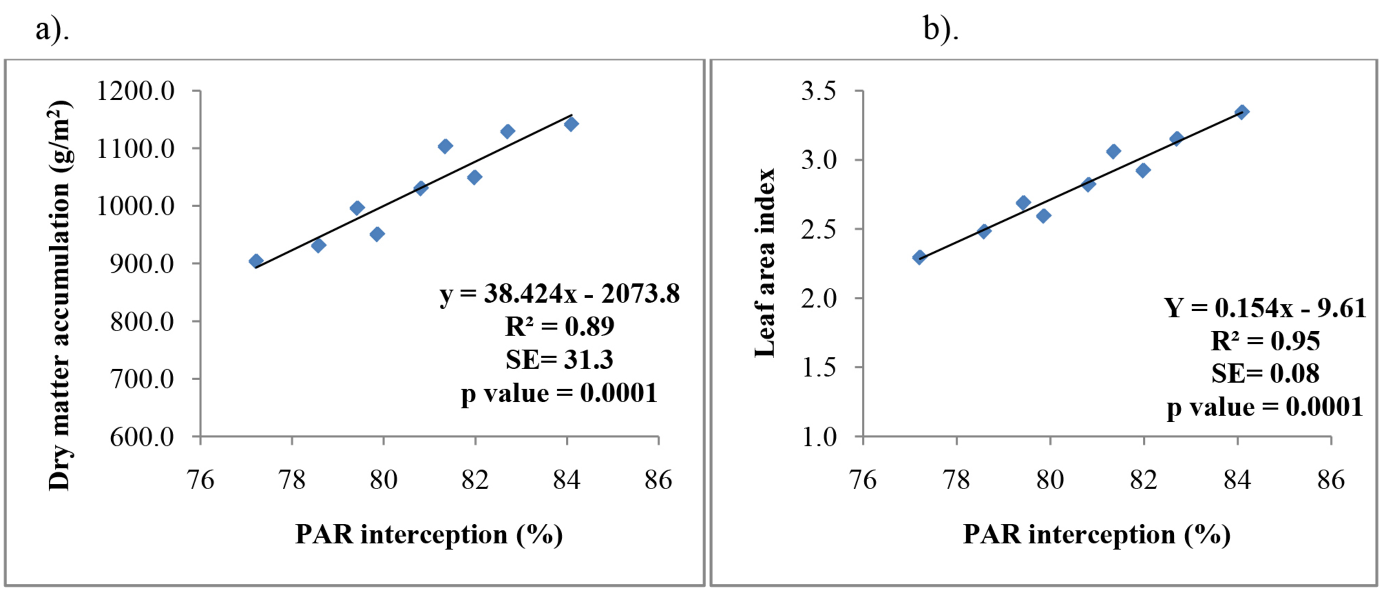

Fig. 1: Relationship between PAR interceptions and (a) dry matter accumulation of wheat and (b) leaf area index of wheat

Radiation use efficiency

Among the dates of sowing, higher radiation use efficiency in timely sowing could be attributed to the highest biomass and grain yield on a pooled basis as depicted in (Table 3). The highest radiation use efficiency (1.79 for biomass and 0.62 for grain) was recorded on the 25th October sown crop, followed by the 15th November (1.76 for biomass and 0.61 for grain) and the 5th December sown crop (1.65 for biomass and 0.54 for grain). There was no statistically significant difference in radiation use efficiency among the varieties. Pradhan *et al*. (2014) also observed a significant positive correlation between RUE and crop yield of wheat.

Table 3: Radiation use efficiency of different wheat varieties under different sowing dates during (pooled data over two years 2017-18 and 2018-19)

	Radiation use efficiency (g mJ^{-1})	
Treatments	Biological yield	Grain yield
Dates of sowing		
October 25	1.79	0.62
November 15	1.76	0.61
December 5	1.65	0.54
S.Em±	0.02	0.01
CD (p=0.05)	0.05	0.03
Varieties		
PBW-725	1.73	0.59
PBW-677	1.72	0.58
HD-3086	1.73	0.60
S.Em±	0.02	0.01
CD (p=0.05)	NS	NS

Relationship between PAR interception, dry matter and LAI

A positive and significant relationship was observed between PAR interception, dry matter accumulation and leaf area index (Fig. 1. a and b). On the basis of pooled analysis, the coefficient of determination (R^2) revealed that dry matter accumulation and leaf area index explained 89 and 95 percent of the variation in grain yield. Wajid *et al.* (2004) concluded that normal sowing (10^{th} November) resulted in higher biomass production with higher leaf area index, thus intercepted more of the available radiation within the canopy i.e., in many crops, 80-85 percent of radiation is intercepted when LAI is between 3.0 to 4.0 and 95 percent is intercepted when LAI reaches 5.0.

The results revealed that crop sown on October 25^{th} took maximum calendar days and accumulated more heat units and photo-thermal units, which were significantly reduced with the subsequent delay in sowing (December 5). The radiation use efficiency was found to be highest under the October 25 sown crop. The normal sowing resulted in higher biomass production with higher leaf area index, thus intercepted more of the available radiation within the canopy which enhances the yield of crop. So sowing time in wheat plays a significant role in deciding wheat yield under Punjab conditions.

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REFERENCES

Dhaliwal, L.K., Chahal, S.K., Hundal, S.S., and Singh, H. (2006). Effect of meteorological parameters on wheat productivity under Punjab condition. *Agric. Res. J.,* 43: 1-5.

FAO, (Food Agriculture Organization). (2017). FAOSTAT crop data. http://www.fao.org/faostat/en/#data/QC

Kaur, S., Singh, S.P., and Kingra, P.K. (2016). Relationship of wheat yield with agroclimatic indices under varying thermal regimes, nitrogen levels and stress management strategies. *Int. J. Bio. Res. Stress. Manage*. 7(4):870-76. http://dx.doi.org/10.23910/IJBSM/2016.7.4.1595

Mehta, P., and Dhaliwal, L.K. (2020). Effect of different sowing dates on helio-thermal, phto-thermal and heat use efficiencies and productivity of wheat (*Triticum aestivum* L.). *J. Agric, Physics*., 20: 106-119.

Nuttonson, M.Y. (1955). Wheat climate relationship and use phenology in ascertaining the thermal and photothermal requirement of wheat. American Institute of Crop Ecology, Washington DC, 338.

Pradhan, S., Sehgal, V.K., Sahoo, R.N., Bandyopadhyay, K.K., and Singh, R. (2014). Yield, water, radiation and nitrogen use efficiencies of wheat (*Triticum aestivum*) as influenced by nitrogen levels in a semiarid environment. *Indian J. Agron.,* 59: 267-275.

Ram, H., and Gupta, N. (2016). Productivity, yield attributes and phenology of wheat (*Triticum aestivum* L.) under different sowing environments under central Punjab. *J. Wheat. Res.,* 8: 34-38.

Wajid, A., Hussain, A., Ahmad, A., Rafiq, M., Goheer, A.R., and Ibrahim, M. (2004). Effect of sowing date and plant density on growth, light interception and yield of wheat under semi-arid conditions. *Int. J. Agric. Biol.,* 6: 1119-123.doi.1560–8530/2004/06–6–1119–1123.