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Research Article

Variability in Photosynthetically Active Radiation Interception and its Extinction within Wheat Cultivars Sown at Different Dates in Irrigated Plains of Punjab

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ABSTRACT

A field experiment was conducted during *rabi* 2022-23 at Punjab Agricultural University, Ludhiana to study the variability in Photosynthetically Active Radiation (PAR) interception at different growth stages within canopy of wheat cultivars. The treatments comprised of five cultivars (Unnat PBW 343, Unnat PBW 550, PBW 826, PBW 869 and PBW 824) of wheat planted under six sowing dates (26th October; 2nd November; 9th November; 16th November; 23rd November; 30th November) in a split plot design. The sowing dates influence canopy architecture, i.e. leaf area index (LAI) and extinction coefficient 'k' which in turn affect the interception / albedo of PAR by the canopy. The PAR interception amongst six dates of sowing was highest for 26th October (73.6%) and least for 30th November (66.0%) sowing. Amongst the cultivars, PBW 826 had higher PAR interception under different dates of sowing which could be attributed to better vegetative growth and LAI whereas cv. Unnat PBW 550 had higher interception of PAR under later sown conditions, i.e. in 2nd fortnight of November. The PAR interception was maximum at anthesis stage (87.3%) due to maximum LAI (3.62) and least reflection, i.e. albedo (5.59%) by the canopy. However, at physiological maturity due to senescence, the PAR interception was least and varied between 53.9 to 66.2%. The extinction coefficient 'k' was more under early growth stages (0.52 to 0.76) which was reduced to (0.44 to 0.69) during anthesis and (0.38 to 0.49) at physiological maturity stage. The extinction coefficient increased with delayed sowing due to lower LAI amongst all the cultivars whereas in cv. Unnat PBW 550 the value of 'k' decreased because of more LAI during late sowings. Amongst the cultivars, PBW 826 had the lowest k (0.51) value due to maximum PAR interception while the cv Unnat PBW 550 had the maximum extinction coefficient (0.56). The albedo, i.e. reflection of radiation by canopy increased with delayed sowing due to less vegetative growth of the crop as well as with advancement in crop growth stages.

Key words: Wheat, Extinction coefficient, Leaf area index, PAR, Plant height

Introduction

Wheat (*Triticum aestivum* L.) is a major cereal crop grown globally over nearly 240 million ha, which is more than any other crop (Anonymous, 2023). Solar radiation is the ultimate source of energy which is captured by the plants during the process of photosynthesis. The growth of a crop is dependent on the ability of its canopy to intercept the incoming radiation. Thus the intercepted solar radiation provides the energy for photosynthesis in crops, thereby determining its production potential (Gou *et al.,* 2017). When light is evenly distributed and fully utilized, plant growth and the number of spikes

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per unit area increases, resulting in increased yield. The visible solar radiation is represented by photosynthetically active radiation (PAR) in the 400 to 700 nm wavelength band. The interception of PAR is influenced by the leaf shape and its inclination within the canopy (Pandey *et al*., 2012). The fraction of the incident PAR intercepted by a given crop canopy is a function of its green crop area, *i.e.*, leaf area index (LAI) and its canopy extinction coefficient 'k'. In general, crop development causes differences in light interception (Zhi-qiang *et al*., 2018). Improved biomass, grain yield and water productivity would depend on the capacity of crop to improve the amount of intercepted PAR or the efficiency with which the canopy converts that radiation into new biomass (RUE) at different stages of the crop (Singh *et al*., 2018). The incoming and intercepted PAR may impact crop photosynthetic properties and dry matter (DM) accumulation, both of which are important factors in determining the crop yield efficiency (Liu *et al.,* 2020). Dry matter production and intercepted PAR have a positive relationship (Kaur and Prabhjyot–Kaur, 2016).

The time of sowing of a crop, whether early, normal or late greatly influence the plant population stand while row-row and plant-plant spacing influence the plant distribution in the field and these directly impact the photosynthesis and yield traits (Zhi-qiang *et al*., 2018). A crop's grain yield is determined by the LAI, which measures the canopy's ability to intercept incoming radiation and photosynthesis of leaves. The greater the LAI, the greater will be the interception of PAR by the canopy (Man *et al*., 2017).

The canopy extinction coefficient (k) is a key variable in crop development. The value of k is determined by the canopy structure, crop type, sowing pattern, and stage of development based on mean leaf angle and solar angle (Yahuza, 2011; Soleymani, 2016). Extinction coefficient (k) values have been found to be related to LAI of the canopy (Carretero *et al*., 2010), i.e. higher k values are associated with lower LAI values and vice versa. Crops with narrow, erect leaves have lower k values than crops with more horizontally displayed leaf arrangements (Carretero *et al*., 2010). Indeed, researches have shown that lower k values (more upright leaves) allow for better light penetration into the canopy. In case of wheat plant, the value of k varies between 0.37 to 0.82 (Muurinen and Peltonen-Sainio, 2006).

Wheat is an important cereal crop grown widely in the state of Indian Punjab. During crop year 2020-21 it was cultivated over 3.53 million hectares and yielded an average output of 4868 kg/ha (Anonymous, 2022). The interception of PAR which is guided by canopy architecture (LAI, height of plant, etc) and k at different stages of crop are the major determinants of variations in microclimate within the crop (canopy temperature, soil temperature, etc), growth and yield of a crop. So the present study was undertaken with an objective to assess the variations in canopy characteristics at three growth stages, *i.e.*, jointing, anthesis and physiological maturity of five wheat cultivars grown under six sowing dates.

Material and Methods

Study area

The field trial was conducted at research farm in the Department of Climate Change and Agricultural Meteorology at Punjab Agricultural University in Ludhiana during the *rabi* season of 2022-23. Ludhiana is located in the central irrigated plains of Punjab, at a latitude of 30°54′ N and longitude of 75°54′ E, at an altitude of 247 meters above sea level.

Study design and observations

The experiment was conducted in split plot design with dates of sowing (D_1: 26th Oct, D_2: 2nd Nov, D_3: 9th Nov, D_4: 16th Nov, D_5: 23rd Nov and D_6: 30th Nov) as main plot and cultivars (Unnat PBW 343, Unnat PBW 550, PBW 826, PBW 869 and PBW 824) as sub plot treatments. The wheat crop was sown with *kera* method. Fertilization of the crop was done as per the recommended practices, i.e. DAP (source of N and P) @ 55 kg/acre at the time of sowing while the urea @90 kg/acre was applied through broadcasting in 2 spilt doses, i.e. with first and second irrigation.

The leaf area index (LAI) was measured using a Sun Scan canopy analyser (Delta-T make, Type SS1).

The measurements were taken at 15-day intervals after the crop was 30 days old. The LAI was measured by placing the sensor at two different points below the canopy. The height of plant was taken from the randomly tagged five plants in a plot at 15 days interval. The height was measured with the scale form the ground surface to the tip of the upper fully developed leaf.

The photosynthetically active radiation (PAR) observations at different phenological stages were recorded with line quantum sensor at hourly intervals starting from 1000 am to 1600 hour. The incoming and reflected PAR observations were taken at top of crop canopy while transmitted radiation was measured at the base of the crop. The PAR interception was calculated (Flenet *et al.*, 1996) as:

$$\text{PAR interception (\%)} = \frac{\text{IPAR} - [\text{TPAR} + \text{RPAR}]}{\text{IPAR}} \times 100$$

Where,

IPAR = PAR incoming above the canopy (W/m^2)

TPAR = PAR transmitted in the ground (W/m^2)

RPAR = PAR reflected from the canopy (W/m^2)

The extinction coefficient "k" is ratio between the light fatalities through the leaf to the light that reaches at the top of the leaf. It varies with the arrangement and orientation of leaves in a plant. The extinction coefficient was computed by using the Beer's law given below as:

$$I = I_o \exp^{(-k*LAI)}$$

Where,

LAI = Leaf Area Index

I = Light flux density below the canopy

I_o = Light flux density above the canopy

k = Extinction coefficient

Result and Discussion

Canopy architecture

The data on canopy growth attributes of wheat cultivars at three growth stages under different sowing dates during *rabi* 2022-23 are presented in the Fig 1 (a-c). The plant height decreased with delayed sowing i.e. the crop sown during October 26, 2022 attained maximum height and the least height was attained by the crop sown during November 30, 2022. Among the cultivars Unnat PBW 550 attained the shortest height (76.3 cm) and tallest height (89.5 cm) was attained by cv. PBW 824. The similar findings were reported by Buttar *et al*. (2018), Kaur *et al*. (2018) that wheat plant invariables attains more height under early sowing than late sowing.

The leaf area index (LAI) of wheat increased upto 90 days after sowing with increase in canopy under all sowing dates. When the crop attained its peak and moved during the flowering phase, i.e. when the crop is nearly 90 days old, the LAI started declining, since the crop starts diverting the assimilates from leaf to development of grains and the lowest LAI was observed when the crop starts nearing the physiological maturity stage. The cultivar PBW 826 attained maximum leaf area index. The LAI was reduced with delayed sowing of wheat cultivars. The highest LAI was recorded under the crop sown during the end October (3.18) and least during the end November (2.36). The results of the experiment are in alliance with the findings of Singh *et al*. (2021) as they also reported that LAI is maximum in early sown crop (D_1-25^{th} October) and least in the late sown crop (D_5- 5^{th} December). Hence there is a positive relationship between LAI and plant height for wheat crop cultivated under different dates of sowing. So it may be concluded that with delay in sowing the plant height and LAI of the wheat cultivars decreases.

Characteristics of Photosynthetically active radiation (PAR)

The data on PAR characteristics (incoming, albedo and interception) for wheat cultivars at three growth stages (jointing, anthesis and physiological maturity) are presented in Fig. 2 (a-c). The perusal of the data showed that incoming PAR was least during jointing stage which is realized during January month and then increases during anthesis stage realized during February month and maximum during physiological maturity stage realized during April month. However, the interception of this

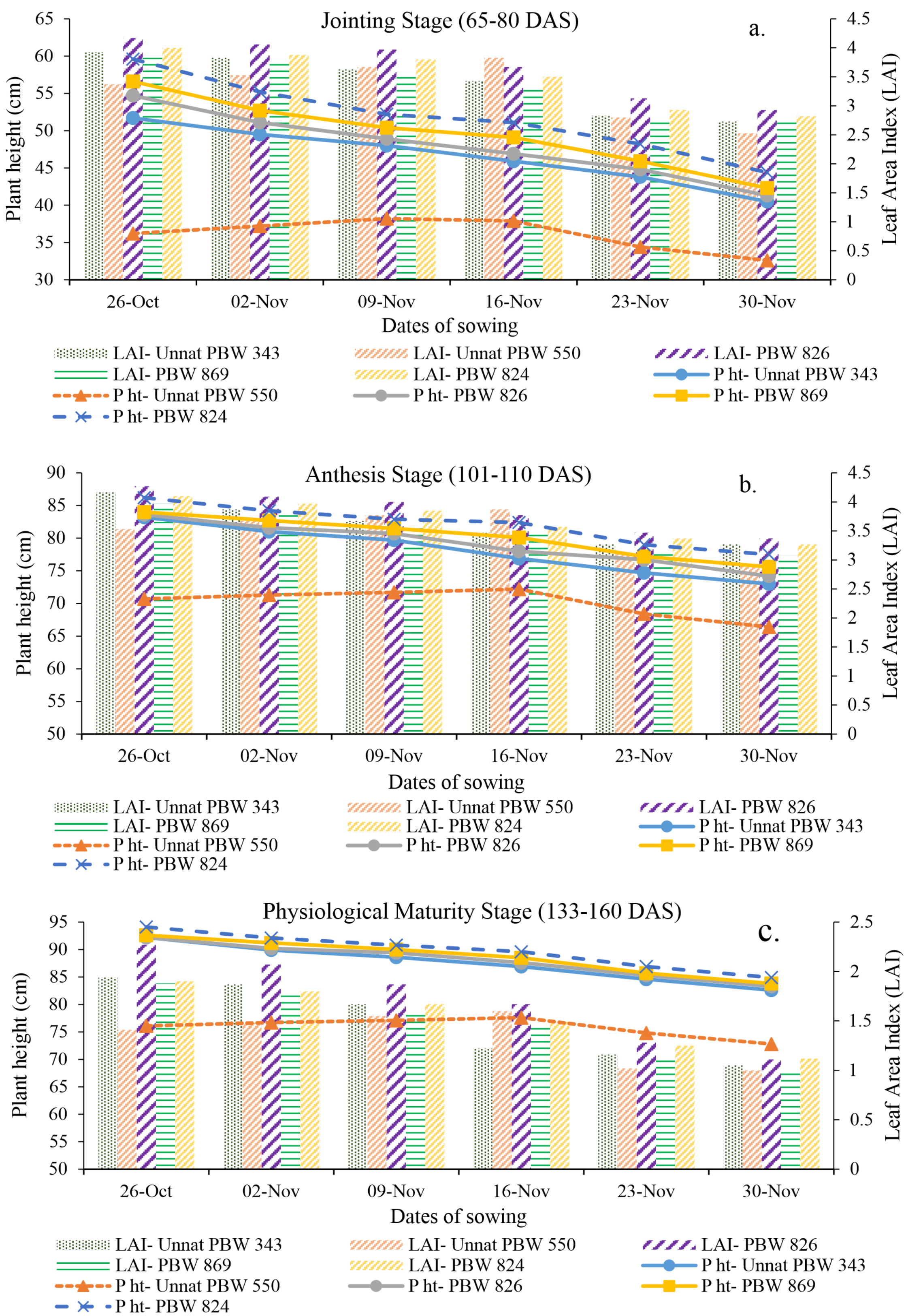

Fig. 1(a-c). Variation in plant height and LAI at different growth stages of wheat cultivars sown from end October to end November

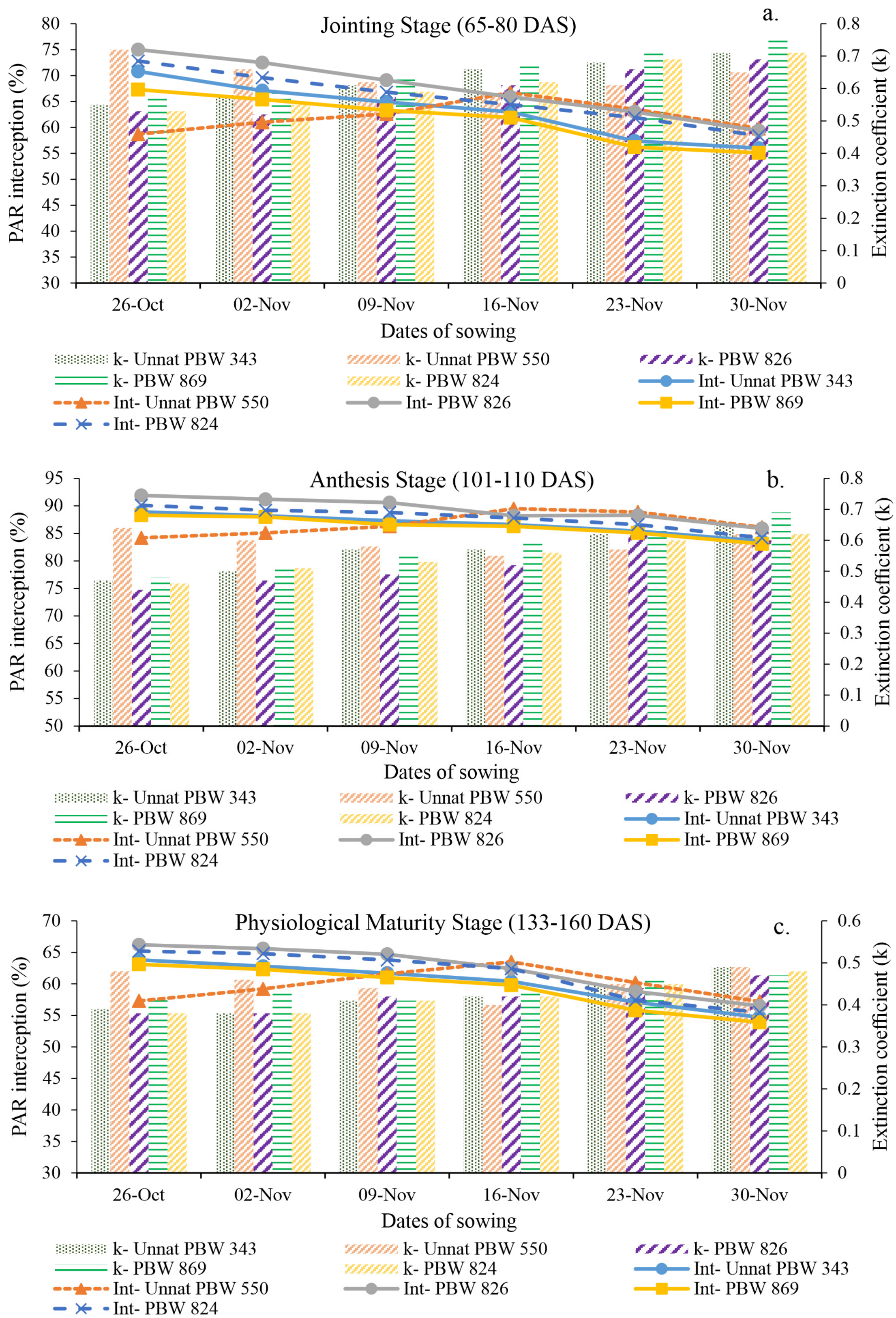

Fig. 2 (a-c). Variation in PAR interception (%) and extinction coefficient (k) at different growth stages of wheat cultivars sown from end October to end November incoming PAR is maximum (>83%) during anthesis stage as the LAI is also at its peak (3.62). The reflection of this incoming PAR, i.e. albedo is least (~4 to 6%) during the anthesis stage. So the crop can harvest the solar radiation most efficiently during the anthesis stage of wheat crop. Later as the crop moves towards its maturity due to leaf senescence though the values of incoming PAR are maximum (297.8-416.5 W m^{-2}) but its interception is lesser (53.9 to 66.2%) while the albedo is more (8.8-11.7%). Amongst the wheat cultivars, PBW 826 was most efficient in intercepting the incoming PAR at jointing (67.5%), anthesis (89.3%) and physiological maturity (62.3%) stage, while cv Unnat PBW 550 could harness only 62.4, 86.6 and 59.8% PAR at jointing, anthesis and physiological maturity stage, respectively. Zhang *et al*. (2009) and Pandey *et al*. (2012) reported that higher interception of PAR is observed in crop with more LAI. In the present study when the LAI is maximum at anthesis stage, then the interception of PAR is also at its peak.

Extinction coefficient (k)

Extinction coefficient (k) determines the ability of the canopy to utilize the radiation falling on the crop. The value of k in a canopy is high when the foliage is dense (more LAI) which is conversely observed during the peak vegetative growth period of the crop. The variations in k at three growth stages of wheat cultivars in relation to PAR interception are presented in Fig. 2(a-c). The delayed sowing decreases the PAR interception due to increase in the extinction coefficient (k). Dhakar *et al*. (2023) also reported that the delayed sowing caused increase in extinction coefficient. The value of 'k' decreases with advance in crop growth. It was lowest at physiological maturity (0.43) while maximum at jointing stage in all the cultivars (0.62). The reduction in 'k' with advancement in crop growth stages was also reported by Kaur and Prabhjyot-Kaur (2016). The variety PBW 826 had lesser extinction coefficient (0.51) as the intercepted radiation was higher as compared to other cultivars sown. The coefficient increased with delayed sowing amongst all the cultivars except in cv. Unnat PBW 550 where the value of k decreased with delayed sowing. The crop sown during end October had lower k (0.49) than the cultivars sown during end November (0.61). In the present study, the k during all the three growth stages ranged between 0.38 to 0.76 and these results coincide with the conclusions drawn by Kukal and Irmak (2020). The study conducted by Pradhan *et al*. (2018) also reported that k value has ranged between 0.41 to 0.78.

Conclusions

In the nutshell, the microclimatic observations were influenced by the different sowing dates in all wheat cultivars. The PAR interception was maximum when the cultivars were sown early, i.e. end October to mid November, while interception of PAR decreased with delayed sowing (3rd week November onwards) due to decrease in the leaf area index. The PAR interception was higher in cv. PBW 826 followed by PBW 824, Unnat PBW 343 and PBW 869 when sown early, while the cv. Unnat PBW 550 had higher PAR interception under the later sown conditions. The refection of radiation, i.e. albedo were more under late sown conditions, extinction coefficient was increased and radiation interception was reduced.

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