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RADIATION INTERCEPTION AND GROWTH DYNAMICS OF WHEAT UNDER DIFFERENT ENVIRONMENTS

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ABSTRACT

Role of radiation interception in growth dynamics of wheat crop sown under different environments was estimated. Three wheat varieties viz. HD 2967, PBW 550 and PBW 343 were sown under three row spacing i.e.15 cm, 22.5 cm and 30 cm on 25th November during 2012-13 and 2013-14 at PAU, Ludhiana. The PAR interception was maximum in 30 cm row spacing where it was 83.2 and 83.0 per cent in HD 2967 and 81.5 and 81.0 per cent in PBW 550 and 83.0 and 82.0 per cent in PBW 343 during 2012-13 and 2013-14. Among varieties, HD 2967 recorded maximum PAR interception (84.1and 83.0 per cent) followed by PBW 343 (83.2 and 81.0 per cent) and PBW 550 (82.1 and 81.0 per cent) in 30 cm row spacing during 2012-13 and 2013-14 respectively. Highly significant R^2-values in the range of 0.50 to 0.74 were found for different treatments. These values indicated that PAR interception significantly influence dry matter accumulation and leaf area index of crop. This study revealed that with change in row spacing radiation interception was influenced which further has an important role in growth dynamics of crop.

KEY WORDS
Row spacing
PAR interception
Dry matter accumulation
Leaf area index

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INTRODUCTION

The interception of light by a canopy is a fundamental requirement for crop growth. Light interception and relationship to crop growth have been important concepts applicable to virtually all crops (Monteith 1977). Although canopy light interception is important for yield prediction and crop growth. All determinants of crop growth, namely radiation utilization, dry matter loss due to respiration, partitioning of assimilates to economically harvestable parts, and duration of crop growth are influenced by the prevailing environmental conditions of radiation and temperature. Efficiency of conversion of radiation into dry matter depends upon plant traits and environmental conditions (Hundal *et al.,* 2004). Abbate *et al.,* (1997) demonstrated that intercepted photosynthetically active radiation (IPAR) was the main factor determining crop growth in wheat.Wheat grain yield and quality are also influenced by temperature regimes during different phases of crop growth. Within the growing season itself, warmer temperature shortens the total crop duration. Higher temperature during early vegetative phase results in sparse tillering, poor vegetative growth and early heading and during grain filling phase leads to forced maturity (Reddy 2006). Climate and weather variability especially temperature significantly affect potential wheat yield under irrigated conditions in Punjab. A better understanding of weather resources can help to increase crop productivity. It will enhance the benefits by minimizing losses due to adverse weather conditions (Virmani 1994).

Temperature, radiation and moisture are basic meteorological parameters of significance to agriculture. Under potential conditions, with adequate moisture and fertility, radiation plays the role of a decisive factor for crop growth and development. Growth and final total yields of crops largely depends on the interception and the efficiency of use of growth resources namely water, nutrient and radiation. Radiation interception depends upon the architecture of the crop and by modifying crop architecture radiation interception can be modified. Thus, manipulation of radiant energy within a crop field by an appropriate adoption of crop stand geometry, like row spacing can provide a means to create light saturated conditions for crop canopy for the purpose of efficient harvest of solar energy for agricultural production. Row spacing can provide a physical barrier between the soil and atmosphere and consequently improve heat conditions at the soil surface. Competition for light penetration, water and essential nutrients availability can be manipulated to enhance production potential of wheat by sowing in different row spacing (Chen and Neill, 2006). Moreover, row spacing may modify the plant architecture, photosynthetic competence of leaves and dry matter portioning in field crops (Samani *et al.,* 1999).

Due to changing climatic scenario there is a need to study the role of radiation interception under different row spacing in production of biomass so we hypothesized to analyse the diurnal pattern of PAR interception in wheat sown under different row spacing with an objective to compare the extent of variation in PAR interception by changing row spacing and effect of this PAR interception on biometric parameters viz. dry matter accumulation and leaf area index of crop under different treatments.

MATERIALS AND METHODS

Experimental site

The present investigation was carried out at the Research Farm, School of Climate Change and Agricultural Meteorology, PAU, Ludhiana during 2012-13 and 2013-14. This study was planned to know the radiation interception and growth dynamics relationships under different growing environments. Three wheat varieties viz. HD 2967, PBW 550 and PBW 343 were sown under three row spacing i.e.15 cm, 22.5 cm and 30 cm on 25th November during both crop seasons.

Measurement of photosynthetically active radiation (PAR)

Diurnal cycles of photosynthetically active radiation (PAR) were taken at hourly interval from 0900 hours to 1700 hours at different phenological stages. A Line Quantum Sensor (Model LI-190 SB) was used to measure the amount of incoming, reflected and transmitted PAR in the range of 400-700nm.

The incoming and reflected radiation measurements were made 1 meter above the canopy while transmitted radiation was recorded at the base of canopy and the sensor base just touching the ground. From these observations, per cent PAR interception in the crop was calculated by using the most common method described by Flenet *et al.*, in 1996. According to this method, formulae is as under:

$$\text{PAR interception}\,(\%) = \frac{\text{PAR(I)} - [\text{PAR(T)} + \text{PAR(R)}]}{\text{PAR(I)}} \times 100 \quad \text{(Eqn. 1)}$$

Where,

PAR (I) – PAR incoming above the canopy

PAR (T) – PAR transmitted to the ground

PAR (R) – PAR reflected from the canopy

Growth dynamics

Dry matter accumulation and leaf area index of crop were recorded at periodic intervals. For dry matter, samples were collected at 15 days interval. They were first air dried in the sun and then oven dried at 60-70°C to constant weight and weighed to obtain the dry matter accumulation of the plant. Green leaf area (cm^2) was recorded at 15 days interval with the help of calibrated Plant Canopy Analyzer (LICOR-make).The leaf area index was measured by placing the sensor once above the canopy followed by placing it at four different points below the crop canopy diagonally across the rows.

Data analysis

PAR interception was calculated by using the above discussed formulae (Equation-1) and relationships were developed between PAR interception and dry matter accumulation as well as PAR interception and leaf area index of crop recorded at 15 days interval using Microsoft EXCEL. Test of significance was applied to know the significance of R^2-values using F-table.

RESULTS AND DISCUSSION

PAR interception in different row spacing

Solar radiation is a flux of electromagnetic energy, which must be intercepted and utilized instantaneously, as it cannot be stored for later use. The importance of radiation lies in the vital role it plays in photosynthesis (Tsubo *et al.,* 2001). The PAR wavelength is documented to be within the range of 0.4-0.7 um (Zhang *et al.,* 2008).

The data on photosynthetically active radiation (PAR) interception (%) is presented (Fig.1 and 2) at heading and soft dough stage of the crop under different row spacing in varieties HD 2967, PBW 550 and PBW 343 during 2012-13 and 2013-14. The PAR interception was minimum during morning hours after that it increased and maximum between 12 noon to 1 pm after that it decreased. Parya *et al.*, (2011) and Jena *et al.,* (2015) also reported similar results. Among different row spacing comparison, the PAR interception was minimum in 15 cm row spacing where it was 79.9 and 80.0 per cent in HD 2967 and 79 and 78.0 per cent in PBW 550 and 79.5 and 78 per cent in PBW 343 during 2012-13 and 2013-14. The PAR interception was higher in wider row spacing than narrow row spacing because in wider rows the solar radiation entered and penetrated the crop canopy at higher rate at the base of crop canopy and crop intercepted more solar radiation whereas in narrow row spacing due to dense crop less penetration at the base of crop so interception percentage was less under narrow row spacing than wider row spacing.

Table 1: Relationship between PAR interception (%) and dry matter accumulation (g/plant) in different varieties of wheat (pooled data of 2012-13 and 2013-14)

Variety/Row spacing	Regression Equation	R^2
V_1R_1	$Y = -0.0003X^2 + 0.0966X + 66.104$	0.740*
V_1R_2	$Y = -0.0003X2 + 0.0808X + 70.109$	0.735*
V_1R_3	$Y = -0.0001X^2 + 0.0545X + 70.209$	0.673*
V_2R_1	$Y = -0.0002X^2 + 0.0834X + 67.197$	0.647*
V_2R_2	$Y = -0.0002X^2 + 0.0736X + 68.779$	0.650*
V_2R_3	$Y = -0.0003X^2 + 0.0896X + 67.874$	0.677*
V_3R_1	$Y = -0.0002X^2 + 0.0727X + 66.614$	0.711*
V_3R_2	$Y = -0.0002X^2 + 0.0731X + 69.251$	0.693*
V_3R_3	$Y = -0.0002X^2 + 0.0649X + 69.529$	0.697*

*Significant at 5% level of significance; Where, V_1 = HD 2967 V_2 = PBW 550, V_3 = PBW343, R_1 = 15 cm, R_2 = 22.5 cm, R_3 = 30 cm, Y = PAR Interception (%), X = Dry matter accumulation (g/plant)

Table 2: Relationship between PAR interception (%) and leaf area index in different varieties of wheat (pooled data of 2012-13 and 2013-14)

Variety/Row spacing	Regression Equation	R^2
V_1R_1	$y = -0.7796X^2 + 5.8496X + 62.747$	0.653*
V_1R_2	$y = 0.3728X^2 + 0.8186X + 70.309$	0.534*
V_1R_3	$y = -0.7176X^2 + 4.8169X + 67.728$	0.712*
V_2R_1	$y = -1.1422X^2 + 6.9517X + 63.004$	0.628*
V_2R_2	$y = -1.1648X^2 + 5.9413X + 65.406$	0.573*
V_2R_3	$y = -1.4497X^2 + 7.7316X + 63.782$	0.751*
V_3R_1	$y = -1.1452X^2 + 6.3524X + 63.116$	0.686*
V_3R_2	$y = -0.6285X^2 + 3.9172X + 67.268$	0.557*
V_3R_3	$y = 0.0473X^2 + 1.6521X + 68.905$	0.506*

*Significant at 5% level of significance; Where, V_1 = HD 2967, V_2 = PBW 550, V_3 = PBW343, R_1 = 15 cm, R_2 = 22.5 cm, R_3 = 30 cm, Y = PAR interception (%) , X = Dry matter accumulation (g/plant)

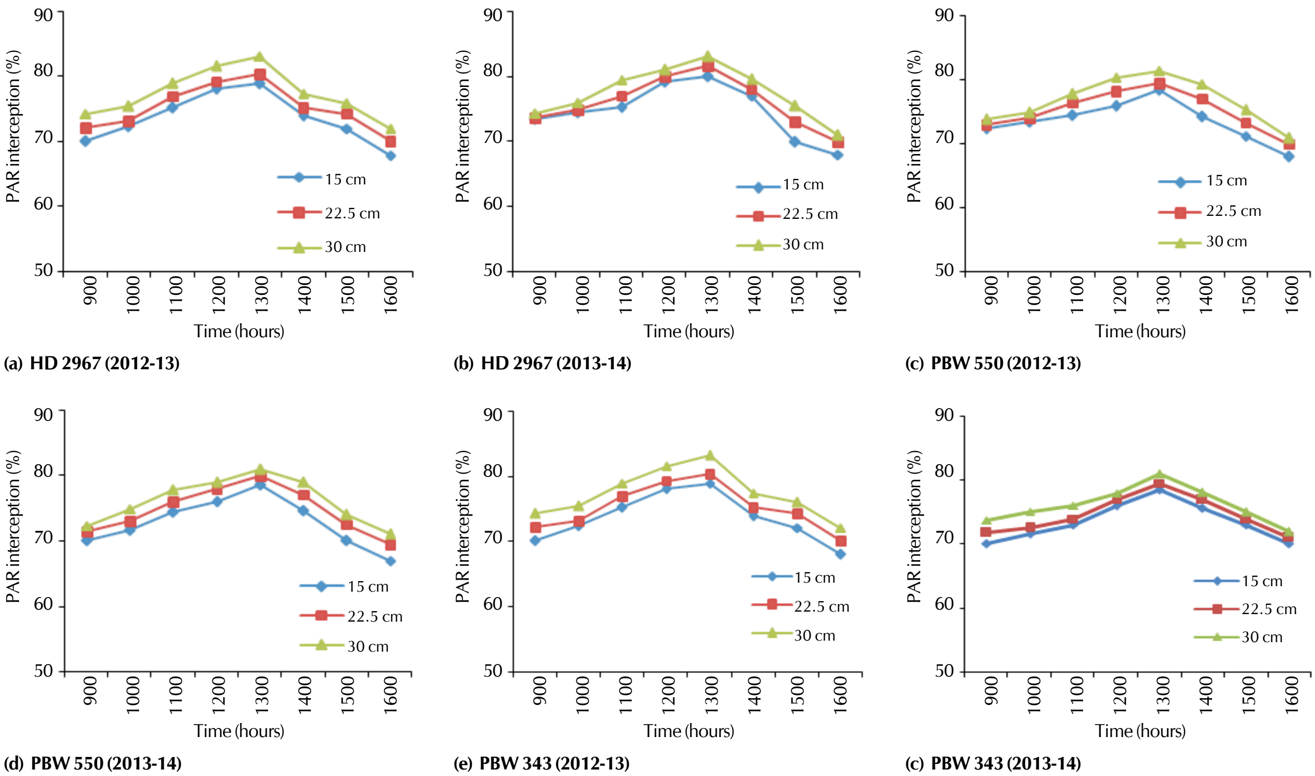


Figure 1(a-f): PAR interception (%) in different wheat varieties under different row spacing at heading stage of crop

Similarly, Eberbach and Pala (2005) also reported that the wider row spacing (30 cm) changed the architecture of winter wheat canopy that resulted in higher interception of incident solar radiation at the soil surface. Kumari *et al.* (2012) also revealed that radiation interception is more under wider row spacing as compared to narrow row spacing crop.

The PAR interception was higher at heading stage than soft dough stage because at heading stage crop was at its maximum vegetative cover but at soft dough stage maximum of green leaves turned yellow so interception decreased. Among different varieties, maximum PAR interception was recorded in variety HD 2967 (84.1and 83.0 per cent) followed by PBW 343 (83.2 and 81.0 per cent) and PBW 550 (82.1 and 81.0 per cent) in 30 cm row spacing during 2012-13 and 2013-14 respectively. As variety HD 2967 showed maximum leaf area index followed by PBW 343 and PBW 550. Zhang *et al.* (2008) also concluded that leaf area influence rate of PAR interception. Variation for PAR interception and LAI among varieties was also reported by Saleem *et al.* (2010) and Ram *et al.* (2013).

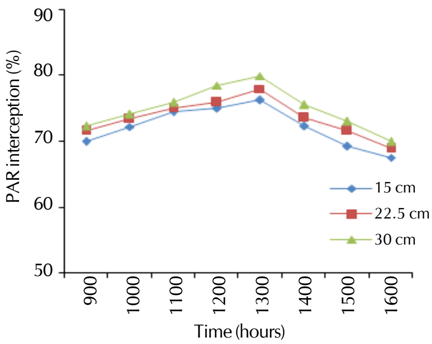
Relationship between dry matter accumulation and PAR interception

The dry matter accumulation (DMA) increases progressively with the advancement of age. The total dry matter production is related to the net photosynthesis. Abbate *et al.* (1995) demonstrated that the intercepted photosynthetically active radiation (IPAR) was the main factor determining crop growth in bread wheat (*Triticum aestivum* L.).

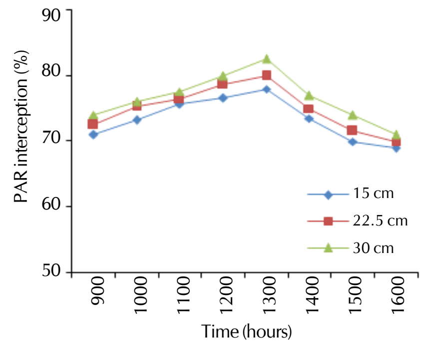
The relationship between dry matter accumulation (DMA) and PAR interception for variety HD 2967, PBW 550 and PBW 343 under different row spacing are presented in the Table 1. Polynomial relationships were found to be best fit between PAR interception and DMA. Relationships between DMA and PAR interception gave signficant R^2-values (Coefficient of determination). In variety HD 2967 sown under 15 cm row spacing, equation indicates that 74.0 per cent variation in dry matter accumulation was due to PAR interception. Whereas in 22.5 cm and 30 cm row spacing, 73.5 per cent 67.3 per cent variation is due to PAR interception respectively. Similarly for other two varieties, significant R^2-values were estimated as presented in Table 1. These findings are in corroboration with findings of Ram Niwas *et al.* (1999) as they also reported a direct and significant relationship between dry matter accumulation and PAR interception in pearl millet cultivars. Hundal *et al.* (2003) also observed a direct and significant relationship between dry matter and PAR interception in mustard cultivars.

Relationship between leaf area index and PAR interception

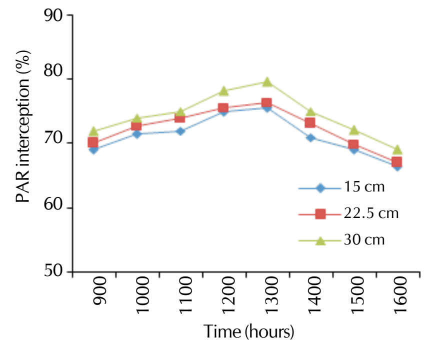
Leaf area index (LAI) increases with increase in crop age and declines at maturity due to senescence of leaves. The per cent PAR interception varied with the leaf area index (LAI). The maximum PAR interception was recorded when LAI was highest. There was a continuous increase in LAI upto 90 DAS of the crop thereafter it decreased. The leaf area index of 15 cm sown crop was higher than 30 cm sown crop it may be due to dense crop growth in narrow sown crop. When crop was approaching to maturity, the leaf area decreased considerably. Kumar *et al.*, (1998) also reported that maximum solar radiation was intercepted at 90 DAS when peak LAI



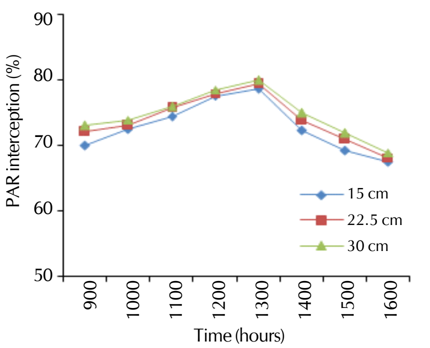
(a) HD 2967 (2012-13)



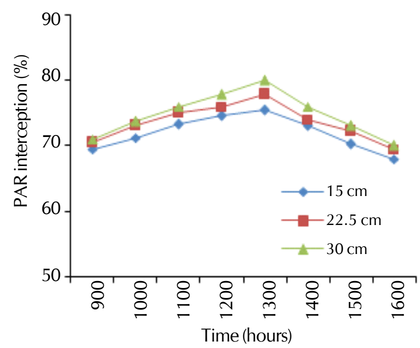
(b) HD 2967 (2013-14)



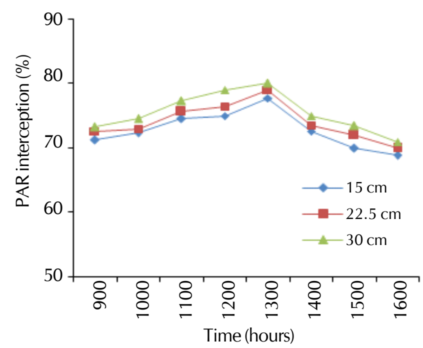
(c) PBW 550 (2012-13)



(d) PBW 550 (2013-14)



(e) PBW 343 (2012-13)



(c) PBW 343 (2013-14)

Figure 2(a-f): PAR interception (%) in different wheat varieties under different row spacing at soft dough stage of crop

occurred in crop.

The regression equations developed between leaf area index (LAI) and PAR interception for variety HD 2967, PBW 550 and PBW 343 under different row spacing are presented in Table 2. These equations gave good estimates under different regression types but polynomial regression type gave best results. Under 15 cm row spacing, R^2-value was estimated as 0.653 that means 65.3 per cent variability in leaf area index was due to PAR interception in variety HD 2967. Similarly, in different varieties under different row spacing good R^2-value was estimated. Yang (2008) reported the effect of row spacing on leaf area, radiation interception and grain yield by performing a field experiment. Similarly, Hussain *et al.* (2012) also reported that narrow row spacing attained higher LAI. Mukherjee *et al.* (2012) also found the positive relationship between LAI and PAR interception under Punjab conditions. Kalpana *et al.* (2014) conducted an experiment on wheat genotypes under different row spacing and results revealed that the more number of tillers m^{-2} and higher leaf area index might be responsible for influencing higher straw yield in 15 cm row spacing.

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