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RESEARCH PAPER

Effect of row orientation on radiation interception and growth dynamics of wheat

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Abstract : The field experiments were conducted at Research Farm, School of Climate Change and Agricultural Meteorology during 2012-13 and 2013-14. This study was planned to know importance of row orientation in radiation interception and growth dynamics of wheat crop. Three wheat varieties *viz.,* HD 2967, PBW 550 and PBW 343 were sown under two row orientation *i.e.* North-South (N-S) and East-West (E-W) on 25th November during both crop seasons. PAR interception, dry matter accumulation and leaf area index were recorded at periodic intervals during both crop seasons. The PAR interception was more in east-west row orientation as compared to north-south row orientation in all the three varieties. Among different varieties, HD 2967 intercepted maximum photosynthetically active radiation due to highest leaf area index of crop. Relationships were developed between PAR interception and dry matter accumulation and leaf area index. Highly significant co-efficient of determination (R^2) were found and these R^2-values indicated that PAR interception significantly influence dry matter accumulation as well as leaf area index of crop.

Key Words : Row orientation, PAR interception, Leaf area index, Dry matter accumulation

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INTRODUCTION

Wheat is a self pollinated crop originated in south east Asia. Wheat is the main cereal crop in India. In India it is second most important food crop, cultivated extensively in North-Western and Central zones. It contributes substantially to the national food security by providing more than 50 per cent of the calories to the people who mainly depend on it. Wheat is one of the important food crop in India and improvement in its productivity has played a key role in making the country self-sufficient in food grain production. However, in the past decade a general slowdown in increase in the productivity of wheat has been noticed, particularly under environments relatively favourable for its growth and development (Nagarajan, 2005). Current estimates indicates that in India alone around 13.5 million hectares of wheat is under heat stress (Joshi *et al.,* 2007). In India, during 2013-14, wheat was grown on 31.30 million hectares with production of 95.80 million tones and per hectare yield of 30.59 quintals. In Punjab, during 2013-14, it was grown on 35.12 lac hectares with production

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of 176.20 lac tonnes and per hectare yield of 50.17 quintals (Anonymous, 2014).

Wheat requires cool climate during the early part of its growth. 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). Perry and Swaminathan (1992) studied that an increase of 0.5°C temperature resulted in decrease in the duration of wheat crop by seven days, which reduced the yield by 0.5 tonnes per hectare in North India.

The important meteorological variables which influence the growth, development and yield of crops are solar radiation, temperature, rainfall, relative humidity and wind velocity (Abbate *et al*., 2004). Key to increasing the productivity of field crops is to maximize the amount of radiation they intercept (Monteith, 1977). Interception of radiations on leaf surface cannot be controlled but can be manipulated for their maximum use by crop husbandry means. The fraction of radiation intercepted by crops increases hyperbolically with LAI in many crops 80-85 per cent is intercepted when LAI is between 3.0 and 4.0, and 95 per cent when LAI reaches 5.0 (Milford *et al*., 1980). Crop growth can be analyzed in terms of its efficiency to use intercepte radiatins. This approach has been applied to many field crops (Hussain *et al*., 2002). The relationship has been used as a basis for theoretical investigations into tropical crop productivity, modeling climate effects and the importance of light as a limiting factor in crop performance (Monteith, 1981). Thus, manipulation of radiant energy within a crop field by an appropriate adoption of crop stand geometry, like row orientation can provide a means to create light saturated conditions for crop canopy for the purpose of efficient harvest of solar energy for agricultural production. An experiment on the effect of row orientation on yield of mustard crop indicated that the seasonal cumulated intercepted photosynthetically active radiation (IPAR) was significantly higher in East-West oriented plots than North-South in both the varieties, whereas, radiation use efficiency (RUE) depended on the crop phenotype. The differences in yield between the two varieties were highly significant at 5 per cent level with the spreading type yielding more. Direction wise, orientation in the East-West yielded more than in North-South (Jha *et al.,* 2012).

Keeping these aspects in view, this study was planned to know the importance of alteration in row orientation of crop in photosynthetically active radiation interception, dry matter accumulation and leaf area index of wheat.

MATERIAL AND METHODS

The present investigation was carried out at 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 two row orientation *viz.*, north-south (N-S) and east-west (E-W) on 25th November during both crop seasons. Photosynthetically active radiation (PAR) was measured 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. Output of Quantum Sensor was recorded with a digital multivoltmeter. Out of incident PAR, a part of the radiation is reflected and scattered and the remaining is absorbed by the canopy or transmitted to the ground surface. 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 by the crop was calculated as under:

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

where,

PAR (I) – PAR incoming above the canopy

PAR (T) – PAR transmitted to the ground

PAR (R) – PAR reflected from the canopy.

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. PAR interception was calculated by using the above discussed formulae 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

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Effect of row orientation on PAR interception:

The PAR interception is an important parameter which depicts the radiation use efficiency of the crop. Radiation also has an important role in water use through effects on evaporation (Singer *et al.*,2011) and transpiration (Kanton and Dennett, 2004). Radiation is the primary driver of the energy and water balance of the soil–plant–atmosphere continuum. The data on photosynthetically active radiation (PAR) interception (%) were recorded at heading and soft dough stage of the crop under different row orientation in varieties HD 2967, PBW 550 and PBW 343 during 2012-13 and 2013-14.

The PAR interception showed variation within different phonological stages. The PAR interception was higher at heading stage in variety HD 2967 followed by PBW 343 and PBW 550 in E-W row orientation during 2012-13 and 2013-14, respectively and lower in N-S row orientation as presented in Table 1. PAR interception was higher at heading stage as compared to soft dough stage. Similarly, Fang *et al*. (2006) also revealed that for winter wheat, more than 70 per cent is the product of photosynthetic matter of green organ produced after heading in the late growing season this was approximately 60 per cent more than that produced by the flag leaves. The PAR interception was maximum in variety HD 2967 followed by PBW 343 and PBW 550 as variety HD 2967 had higher leaf area index (LAI) as compared to variety PBW 343 and PBW 550 so higher LAI, intercepted higher amount of PAR. Ram *et al.* (2013) also observed similar results. They reported that PAR interception was maximum in PBW 343 followed by PBW 550 at 90 days after sowing as LAI was higher in PBW 343 as compared to PBW 550.

Relationship between dry matter accumulation and PAR interception:

Dry matter represents the extent of plant infrastructural build up and consequently the yield bearing base capacity. Periodic monitoring of dry matter is a good index of plant growth rate. Timely accumulation of dry matter by crop is important for adequate transfer of assimilates to the sink and ultimately higher yield. Under adequate supply of water and nutrients, wheat yield has been shown to be closely related to the amount of radiation intercepted during the growing season. Biscoe and Gallagher (1978) showed that 3 g dry matter (DM) of wheat was produced by each mega joule (MJ) of photosynthetically active radiations (PAR) absorbed until ear emergence. For the whole season about 2.2 g DM was produced per MJ absorbed. Such measurements provide a useful index of the production efficiencies of crops in different regions.

The maximum dry matter accumulation was recorded in HD 2967 followed by PBW 550 and PBW 343. Dry matter accumulation was higher in E-W row orientation as compared to N-S row orientation. Net photosynthesis determines the total dry matter production.

Table 1 : Peak PAR interception (%) at different phenological stages in different treatments

Heading stage			Soft dough stage		
Variety/Row orientation	PAR interception (%)		Variety/Row orientation	PAR interception (%)	
	2012-13	2013-14		2012-13	2013-14
V_1R_1	79.0	80.0	V_1R_1	76.3	75.8
V_1R_2	83.2	83.0	V_1R_2	80.0	82.5
V_2R_1	78.5	77.0	V_2R_1	76.0	75.5
V_2R_2	81.5	80.0	V_2R_2	79.5	78.4
V_3R_1	78.2	76.3	V_3R_1	77.0	75.5
V_3R_2	82.7	80.4	V_3R_2	80.5	78.3

Where, V_1= HD 2967 V_2= PBW 550 V_3= PBW 343 R_1= N-S Row orientation R_2= E-W Row orientation

PAR interception influence dry matter accumulation in crops as PAR interception influence photosynthesis by translocation of photosynthates. Relationships were developed between PAR interception and dry matter accumulation in wheat varieties sown in different row orientation. Polynominal relationships were found to be best fit between PAR interception and DMA as presented in Table 2. Relationships between DMA and PAR interception gave higher R^2 values (Co-efficient of determination). Data indicate that 62.6 per cent variation in dry matter accumulation was due to PAR interception in variety HD 2967 in N-S row orientation. Varieties of wheat showed higher value of co-efficient of determination in E-W row orientation. Hundal *et al.* (2003) also observed a direct and significant relationship between dry matter and PAR interception in mustard cultivars. Wajid *et al.* (2004) reported a significant linear relationship between total biomass production and intercepted PAR. High yield thus, require agronomic techniques that produce both a high level of radiation interception and a high rate of conversion of intercepted PAR to grain. Calderini *et al.* (1997) also observed that change in architecture of the canopies in wheat crop influences radiation interception, radiation use efficiency and crop growth rates.

Relationship between leaf area index and PAR interception:

It is well established fact that amount of photosynthetically active radiation (PAR) interception by a crop primarily depends on the distribution of leaf area in time and space. The leaf area index and dry matter accumulation are useful indicators of crop productivity and closely related to PAR interception. Light interception and crop growth rate are largely determined by leaf area index. Thus, an accurate prediction of leaf area index is important to calculate interception of light.

Under field conditions, crop growth is dependent on the ability of canopy to intercept incoming radiation, which is a function of leaf area index (LAI) and canopy architecture and convert it into new biomass (Gifford *et al.*, 1984). The fraction of the incoming photosynthetic active radiation (PAR) that is absorbed by the canopy mainly depends on the LAI and crop geometry (Plenet *et al.*, 2000).

LAI was lower during the earlier stages of crop growth. There was continuous increase in LAI upto 90 DAS and LAI was maximum at 90 days after sowing. Considerable differences in LAI was observed during 60 DAS and 120 DAS. LAI of E-W row orientation crop was higher than N-S row orientation crop. The relationships between PAR and LAI were developed in

Table 2: 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 orientation	Regression equation	R^2
V_1R_1	$Y = -0.0002X^2 + 0.0525X + 72.071$	0.626*
V_1R_2	$Y = -0.0001X^2 + 0.0331X + 73.661$	0.689*
V_2R_1	$Y = -0.0003X^2 + 0.0648X + 71.445$	0.520*
V_2R_2	$Y = -0.0001X^2 + 0.0318X + 73.361$	0.542*
V_3R_1	$Y = -0.0003X^2 + 0.0705X + 70.794$	0.588*
V_3R_2	$Y= -0.0001X^2 + 0.0348X + 72.906$	0.554*

where, * indicate significance of value at P=0.05 V_1= HD 2967 V_2= PBW 550 V_3= PBW 343 R_1= N-S Row orientation R_2= E-W Row orientation Y= PAR Interception (%) X= Dry matter accumulation (g/plant)

Table 3 : Relationship between PAR interception (%) and leaf area index in different varieties of wheat (pooled data of 2012-13 and 2013-14)

Variety/Row orientation	Regression equation	R^2
V_1R_1	$Y = -0.4394X^2 + 4.1365X + 66.884$	0.754*
V_1R_2	$Y = -1.1697X^2 + 6.6289X + 65.365$	0.682*
V_2R_1	$Y = -0.3479X^2 + 3.9716X + 66.467$	0.747*
V_2R_2	$Y = -0.904X^2 + 5.5106X + 64.393$	0.719*
V_3R_1	$Y = -2.4463X^2 + 10.847X + 61.724$	0.617*
V_3R_2	$Y= -1.0629X^2 + 5.5662X + 65.532$	0.718*

Where, * indicate significance of value at P=0.05 V_1= HD 2967 V_2= PBW 550 V_3= PBW343 R_1= N-S Row orientation R_2= E-W Row orientation Y= PAR interception (%) X= Leaf area index (LAI) different wheat varieties sown in different row orientation and are presented in Table 3. It is evident from the data values that LAI is influenced by PAR interception. Similarly, Lunagarhia and Shekh (2006) observed that light interception per cent measured at different depths of the canopy was affected by row orientation. Ridging the land in East-West direction (E-W) caused more light to penetrate in the canopy than North-South (N-S). Higher R^2 values indicate that a significant variation in LAI was influenced by PAR interception. Pandey *et al.* (2004) reported that the maximum PAR interception was observed during the reproductive stage of wheat. The intercepted PAR accounted for 81 per cent variation in biomass and 63 per cent variation in LAI. Similarly, Maddonni and Otegui (1996) developed relationships between green leaf area index (GLAI) and fraction of intercepted photosynthetically active radiation (fIPAR) and they recorded higher R^2 value of 0.81. Chen and Neill (2006) reported that competition for light penetration, water and essential nutrients availability can be manipulated to enhance production potential of wheat by sowing in opposite row spacing. El-maksoud Abd (2008) reported that for plant height, ear leaf area, LAI, ear height, ear length, ear diameter, grain number/row and/ear, 100-grain weight, ear grain weight and grain yield the East-west (E-W) row orientation was superior than the North-south (N-S) row orientation.

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