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Relationship between NDVI, LAI, fIPAR in wheat Under Reduced Solar Radiation in Delhi NCR Region

Brijesh Yadav[1*], Anil Kumar Verma[2], Sushil Kumar Kharia[1], Avinash Goyal[1], Ravi Kumar Meena[2] and Chiranjeev Kumawat[2]

[1]Divison of Agricultural Physics, [2]Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi 110012, India
**Corresponding author*

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A B S T R A C T

A field experiment was carried out at the farm of ICAR-Indian Agricultural Research Institute, New Delhi during rabi season of 2014-15 and 2015-16. The study was conducted to observe response of wheat under reduced solar radiation. In this experiment, three wheat cultivars namely, HD 2967, WR 544 and PBW 502 were grown under five solar radiation reduction treatments i.e. R1 (control), R2 (20% shading), R3 (35% shading), R4 (50% shading) and R5 (75% shading) levels. Ground held spectroradiometer was used for spectral reflectnance measurement of wheat canopy. Finally normalized difference vegetation index (NDVI) was calculated for different treatments. The different regression equations between LAI -NDVI and fIPAR-NDVI were developed for different treatments for both years. The positive correlations were observed for all treatments during both years. Spectral radiance of blue band (400-500nm) was more inside the severe shading compared to mild shading and control. But spectral radiance of red band (620-700nm) was less inside the severe reduced radiation treatments in both the seasons.

Introduction

Solar radiation is the ultimate energy source for plants to regulate the growth and development. Solar radiation reaches the Earth's surface either as direct ray without scattering from the Sun or in diffuse form after scattering through atmospheric constituents. The sum total of the direct and diffuse radiations reaches the Earth's surface is known as global radiation. As a consequence of increase in aerosol content, black carbon and air pollutants, light dimming or reduction in global solar radiation have become a major challenge for crop production in many areas of the world. Long-term observations confirmed that global solar radiation has a widespread declining trend in many parts of the world (Liepert, 2002 and Liu *et al.*, 2004). India also shows a steady light dimming condition since 1960s (Wild *et al.*, 2005 and Ramanathan *et al.*, 2005). Many researchers have been observed that mean annual diffuse radiation is 92.6 Wm−2, with a mean standard deviation of 4.7 Wm−2 through whole Delhi (Soni *et al.*, 2012). India also shows a decreasing trend of solar radiation with – 0.86 W/m2 since 1981 (Kumari *et al.*, 2007). Aerosol, significantly affect, the plant growth and development through changing the upcoming photosynthetically active radiation (PAR, 400-700 nm) as well as short wave radiation. Atmospheric aerosol content, air pollutant and black carbon have been able to scatter and absorb the incoming solar radiation and ultimately increase the diffuse fraction (Greenwald *et al.*, 2006).

Diffuse light has a higher blue: red light ratio which may enhance photochemical reactions and stomata activity (Urban *et al.*, 2012). It also modifies the quality of light spectrum (Bell *et al.*, 2000). Li *et al.*, (2010) suggested that with increasing shading intensity, blue light (400–500 nm) fraction increases but red light (600–700 nm) decreases. Keeping in view the importance of radiation dimming present study was conducted to study the growth pattern of wheat crop under reduced solar radiation.

Materials and Methods

Site characterization

The experiment was carried out at research farm of Indian Agricultural Research Institute (IARI), New Delhi (28°37' N latitude, 77°09' E longitude). The soil of experiment site was sandy loam having pH 7.3, organic carbon 0.47 percent, available nitrogen 170.6kg ha^{-1}, and available phosphorus 18.6 kg $ha^{-1}$and available potassium 275.0kg ha^{-1}.

Experimental details

In this experiment, three wheat cultivars (HD 2967, WR 544 and PBW 502)were grown under five solar radiation treatments i.e. R1 (no shading), R2 (20% shading), R3 (35% shading), R4 (50% shading) and R5 (75% shading) during rabi season of 2014-15 and 2015-16. In this experiment split plot design was followed with three replications in 5 m × 3 m plots. A dose of 120:60:60 kg $ha^{-1}$of N: P: K was applied (three split dose of N as basal, CRI and flowering).

Spectral distribution of insolation

Ground held spectroradiometer was used for spectral reflectance measurement of wheat canopy in the field. The spectral data were processed and exported by ASD View Spec Pro software to MS excel. Finally normalized difference vegetation index (NDVI) was calculated by using equation given by Rouse *et al.*, (1974).

NDVI= (NIR-R) / (NIR+R)

Where,

NIR- Near infrared band (841-876 nm)

R - Red band (620-670 nm)

Leaf Area Index measurement

LAI were measured weekly by using LAI-2000 Plant Canopy Analyzer (LI-COR, USA).LAI readings was measured in each plot and then averaged them for each plot.

Photo synthetically Active Radiation (PAR)

The incoming photo-synthetically active radiation (PAR) was measured from plant canopy and reflected from soil by using line quantum sensor (LICOR- 3000, U.S.A.). Different fractions of photosynthetically active radiation (PAR) like intercepted photosynthetically active radiation (IPAR), fraction IPAR (fIPAR) and absorbed PAR (APAR) were calculated by using following formulas:

IPAR = I0 – It

APAR = (I0+ Ie) - (Ir+It)

fIPAR = (I0-It) / I0

Where,

I0 = Incident PAR at the top of the canopy

It = Transmitted PAR at the bottom of the canopy

Ir = Reflected energy flux from plant canopy
Ie = Reflected energy flux from soil surface

Results and Discussion

Spectral radiance

The spectral radiance of wheat varieties were influenced by the degree of reduced radiation during 2014-15 and 2015-16. More spectral radiance was received by R1 treatment followed by R2, R3, R4 and R5 respectively (Fig 1). A sharp reduction was observed in 759 nm band in rabi 2014-15 and 760 nm in rabi2015-16. Spectral radiance of blue band (400-500nm) was more inside the severe nets compared to mild net and open condition. But spectral radiance of red band (620-700nm) was less inside the severe reduced radiation treatments in both the seasons.

Fig.1 Effect of reduced solar radiation on spectral radiance in wheat crop during rabbi season (A) 2014-15 (73 DAS) and (B) 2015-16 (78 DAS)

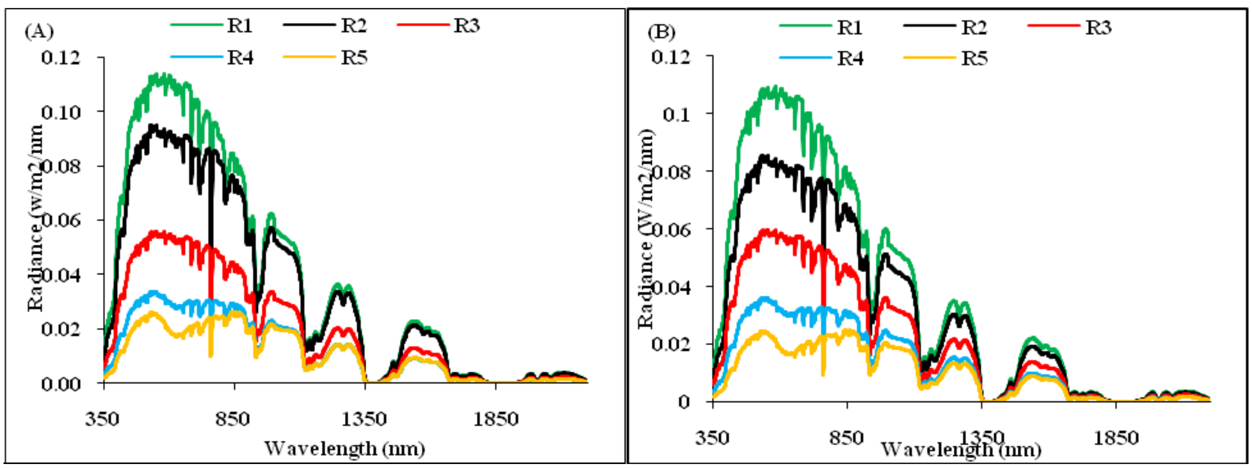


Fig.2 Effect of reduced solar radiation on percent reduction in different wavelength in wheat crop during rabi season (A) 2014-15 (73 DAS) and (B) 2015-16 (78 DAS)

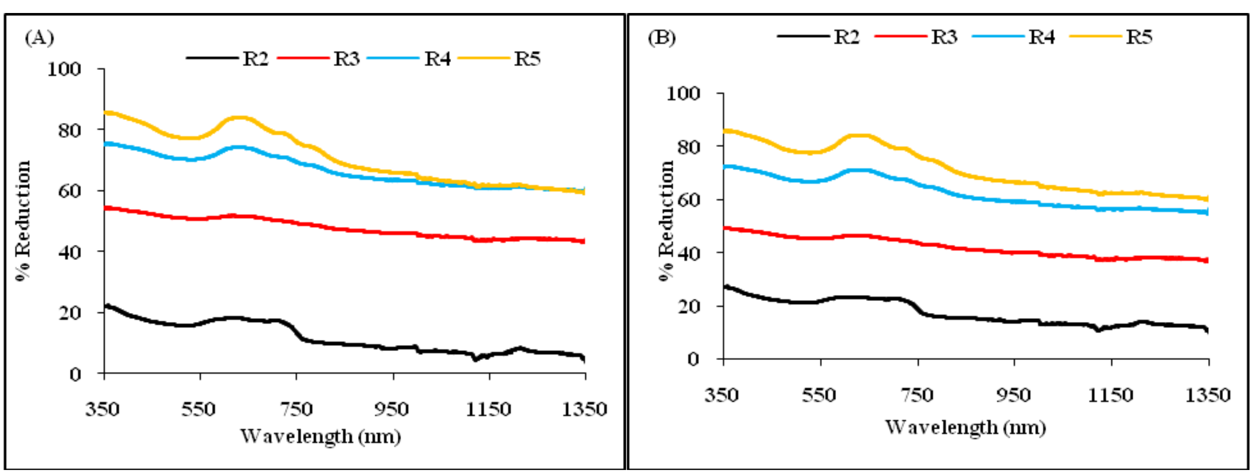


Fig.3 Relationship between NDVI and LAI (A) 2014-15(B) 2015-16 at 78 DAS

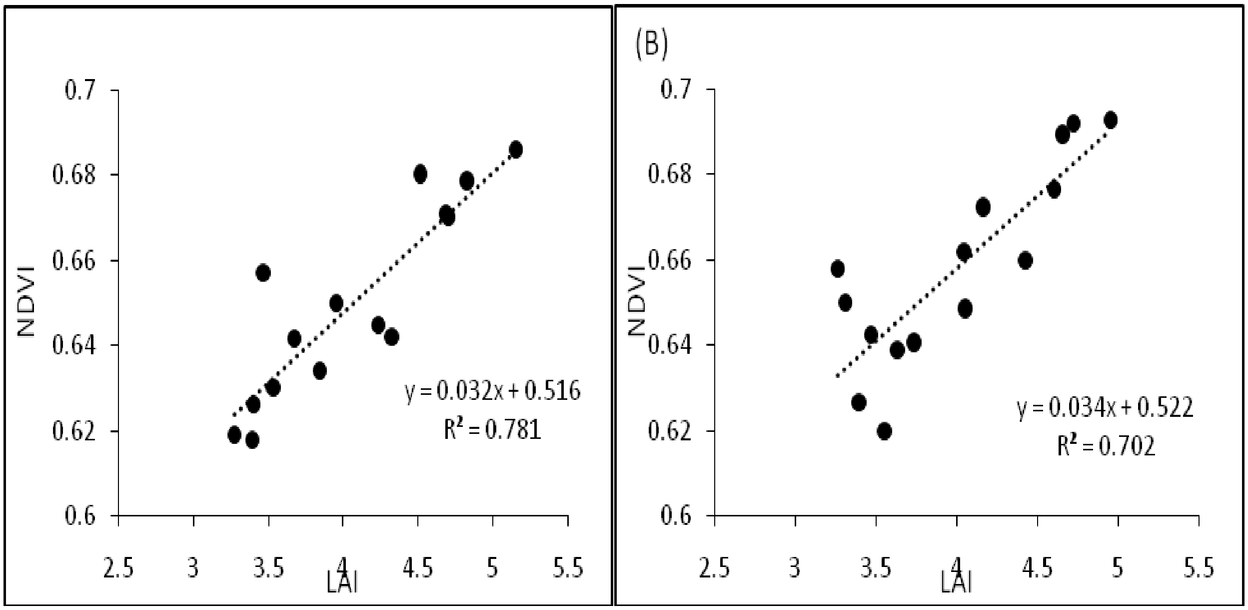
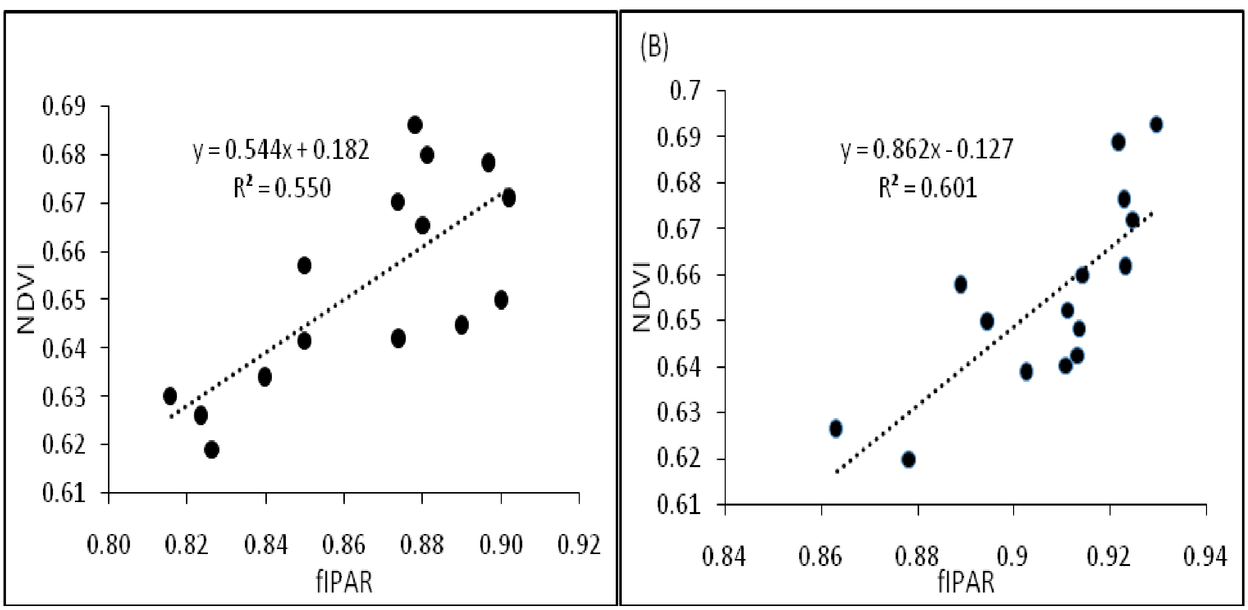


Fig.4 Relationship between NDVI and fIPAR (A) 2014-15 (B) 2015-16 at 78 DAS



Per cent reduction of spectral radiance in both the year showed that under R5 two reduction deep occurred in two bands (375-446 nm and 593-697 nm), in R4 reduction deep occurred in one band (593-697 nm), in R3 reduction deep occurred in one band (591-689 nm) and in R2 reduction deep occurred in (575-765 nm) (Fig.2).

Relationship of NDVI with LAI

The regression equations between LAI versus NDVI for different treatments during 2014-15 and 2015-16 are presented by Fig.3. The positive correlations were observed for all treatments during both years. It was found that value of coefficient of determination was maximum for linear. In year2014-15, the value of R2for linear was 0.78 while during 2015-16 R2value was 0.70. Hence, this relation was found best suitable for the estimation of LAI from NDVI.

Relation between NDVI and fIPAR

The regression equations between NDVI and fIPAR for different treatments during 2014-15 and 2015-16 are presented by Fig. 4. The correlation was positive for all treatments during both years. In year 2014-15, the value of R2 for linear was 0.55 while during 2015-16 R2 value was 0.60 with linear relation. Hence, this relation was found best suitable for the estimation of fIPAR from NDVI.

In conclusion, reduced solar radiation can adversely affects the plant growth and yield of wheat. Spectral radiance or signature of wheat was also influenced by the degree of reduced radiation. More spectral radiance was received by R1 treatment followed by R2, R3, R4 and R5 respectively. Spectral radiance of blue band (400-500nm) was more inside the severe nets compared to mild net and open condition. The regression equations between LAI -NDVI and fIPAR-NDVI were developed for different treatments during 2014-15 and 2015-16. The positive correlations were observed for all treatments during both years.

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