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Effect of wavelength and view zenith angle on the polarization characteristics of wheat canopy

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ABSTRACT

A filed experiment was conducted to optimize the wavelength and the view zenith angle for detection of growth stages of wheat crop through its polarization signatures in visible and infrared spectra. The results indicated higher degree of polarization (DOP) in blue region than in infrared. Crop growth stage, wavelength and view zenith as well as their mutual interactions had significant influence on the DOP measurement. The analysis also suggested superiority of the blue region at 75° view zenith and that of the infrared region at 45° to detect heading and flagleaf transition phases respectively. The peak value of DOP in either spectral region can be used to identify the jointing stage.

Key words : Wheat canopy, Polarization, Wavelength, View zenith angle

Conventional remote sensing methods for resource managment use spectral reflectance behaviour of different surface features for their identification and discrimination. Various spectral indices derived therefrom are made use of for enhancement of their contrasting spectral nature. When such studies made on temporal basis, the temporal dynamics in the objects' spectral signature can be understood. Spectral reflectance profiles have been generated for various crop canopies (Tucker *et al.*, 1980; Patel *et al.*, 1986; Mehta *et al.*, 1989 ; Mehta and Venkatesh, 1990). Most such studies suggest the stage at which spectral data have to be acquired for crop yield predictions and also analyze the discriminability between differenetially stressed crop and between cultivars of the same crop. Sharma and Navalgund (1989) attempted to predict crop growth stages in wheat using the greenness vegetation index. In this context, however, the polarization characteristics of crop canopy have been found to be more useful. Radeaux and Herman(1991) showed that different crop fields exhibited unique polarization signatures and pointed to its utility in detecting tasseling in corn. In case of wheat, it is noticed that it is possible to detect the onset of heading stage through the intensity of polarized radiance (Ghosh *et al.*, 1993). They also revealed pronounced polarization effects at view zenith angle of 80° in the blue wavelength region, whereas Talmage and Curran (1986) found specific polarization characteristics of different surface features from off-nadir angles. With these factors in

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view, an experiment was conducted to optimize the wavelength and the view zenith angle to help identify the different growth stages in wheat crop.

MATERIALS AND METHODS

Wheat Crop (*Triticum aestivum L.*) Cv. Lok-1 was sown on Nov. 26,1990 in two replications on the Agricultural College Farm of the Gujarat Agricultural University, Anand (22° 35 ` N and 72° 55` E). The seed rate, row spacing, fertilizer and irrigation levels were maintained as per the package of practices recommended for the region (Middle Gujarat Agroclimatic Zone). Phenological observations were made regularly during the crop growth period.

Measurements

On field polarimetric measurements in visible (blue) and infrared regions of the electromagnetic spectrum were carried out using an ISRO fabricated multiband ground truth radiometer positioned one meter above the canopy. The radiometer was mounted on a tripod rotatable in three dimensions to enable measurements of the view and the azimuth angles. The blue and the infrared polarization filters were fitted alternately on the radiometer, and measurements of the highest (R_{max}) and the lowest (R_{min}) intensities of radiance corresponding to the plane polarized light perpendicular and parallel to the plane of incidence were made. The measurements were made between 1000-1200 hrs IST on nine different days during the crop growth, covering the phenological phases from tillering to milking. The data from the crop were acquired at four different view zenith angles, viz., 30°, 45°, 60° and 75°. The relative azimuth between sun and view angles was fixed at 180° to ensure maximum specularity (Ghosh *et al.*, 1993; Vanderbilt *et al.*, 1985).

The degree of polarization (DOP) was computed for each set of maximum and minimum signals as:

$$DOP = (RQ/RI)\ 100 \quad \text{.................(1)}$$

where, $RQ = 1/2\ (R_{max} - R_{min})$

$RI = 1/2\ (R_{max} + R_{min})$

The values of DOP obtained at each view zenith angle and spectral region on all the days of observation were averaged for each phenophase basing on the on - field phenological observations during the crop growth. The phenological stage - wise DOP values were then subjected to statistical analysis through the analysis of variance, and inferences are made accordingly.

RESULTS AND DISCUSSION

Temporal variation of degree of polarization

The variation of degree of polarization during the crop growth period in respect of the two spectral regions, irrespective of the view zenith, is presented in Fig. 1. It is observed that the DOP is higher in the blue region throughout. The DOP reaches a peak around 55 days after sowing (DAS) in both the spectral regions. This period corresponds to the jointing stage of the crop. Similarly, variation of DOP with respect to the changes in view zenith angle irrespective of the wavelength (Fig.2), suggests a dominant peak at 45° view zenith at 55 DAS and a secondary peak at 75 DAS. The variations at other view zenith angles show milder fluctuations, with rela-

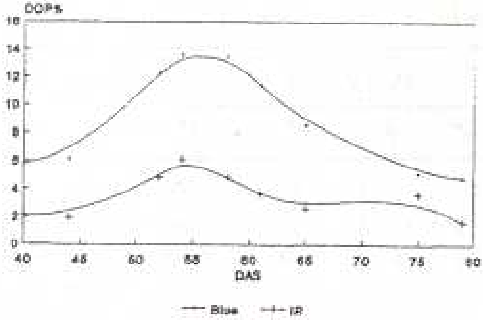

Fig.1 Variation of DOP in Different Spectral Regions during Wheat Growing Period

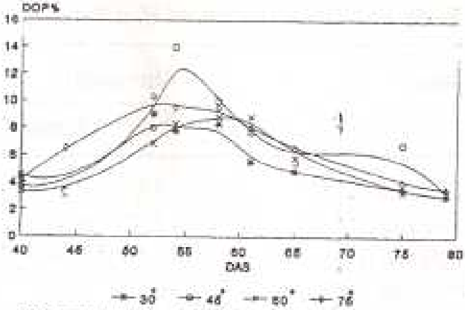

Fig.2 Temporal Variation of DOP at Varying View Zenith Angles

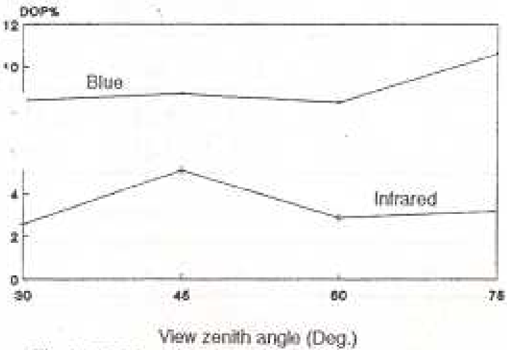

Fig. 3 : DOP in different spectra at different view zeniths

Table 1 : Test on influence of treatments on DOP

Treatment	Degrees of freedom	Calculated 'F' value	Table 'F' Value		Test
			at 95% level	at 99% level	
Stage (St)	3	63.09	2.91	4.48	**
Wavelength (WL)	1	329.67	4.16	7.53	**
St x WL	3	18.16	2.91	4.48	**
Zenith (Ze)	3	7.24	2.91	4.48	**
St x Ze	9	2.62	2.20	3.04	*
WL x Ze	3	7.85	2.91	4.48	**
St x WL x Ze	9	1.46	2.20	3.04	NS

Significant at 95% level ** Significant at 99% level NS Non - significant

Table 2 : DOP as influenced by different treatments

Stage	Wavelength		View Zenith				Mean
	Blue	Infrared	30°	45°	60°	75°	
Tillering (TL)	7.60	2.37	5.00	4.17	3.80	6.95	4.98
Jointing (Jt)	15.37	6.18	9.89	12.64	9.12	11.46	10.77
Flagleaf (FL)	12.54	3.90	6.41	8.43	8.94	9.10	8.22
Heading (He)	6.31	3.57	4.20	6.50	3.90	5.00	4.94
Mean	10.45	4.00	6.38	8.00	6.43	8.12	

Wavelength	View Zenith Angle			
	30°	45°	60°	75°
Blue	9.72	9.94	9.65	12.51
Infrared	3.04	6.03	3.21	3.74

WL x Ze		Crop stage			
		TL	Jt	FL	He
Blue	30°	7.58	15.31	10.05	5.90
Blue	45°	6.25	15.61	12.52	5.40
Blue	60°	5.85	13.38	13.63	5.73
Blue	75°	10.69	17.18	13.95	8.20
IR	30°	2.42	4.47	2.77	2.50
IR	45°	2.10	9.66	4.33	8.03
IR	60°	1.74	4.85	4.26	1.97
IR	75°	3.21	5.75	4.24	1.75

CD for stage = 1.21
WL = 0.86
Ze = 1.21

CD for St x WL = 1.71
St x Ze = 2.42
WL x Ze = 1.21
CV = 19.5%

tively higher values during 50 - 60 DAS.

From Fig.3, wherein the variations of DOP in the two spectral regions *vis - a - vis* view zenith are shown, it is evident that the DOP is higher at 75° view zenith in blue region, whereas in the infrared region it is higher at 45°, thus suggesting the influences between each other.

Identification of crop growth stages

The polarization measurements made on nine different days during crop season were averaged phenological stage-wise to arrive at four sets of data corresponding to the four stages - tillering, jointing, flagleaf and heading. The results of the analysis of variance performed on these data sets are presented in Table 1. All individual treatments imposed, i.e., crop stage (St), wavelength(WL) and zenith angle (Ze) as well as the interaction St x WL and WL x Ze showed significant influence at 99 per cent level on the degree of polarization. The interaction St x Ze resulted in significant variations in DOP measurements at 95 per cent level. Thus for purpose of anlaysis of variations in DOP through different stages, it is noticed that, the spectral region and the view zenith angle individually had significant impact and hence their role may be optimized for discrimination of growth stages.

From the table of means (Table 2) it is observed that the peak DOP occured at the jointing stage for all view zeniths, but the subsequent drop occured variously. While significant drop from jointing to flagleaf is noticed at 30° and 45° view zenith, similar variation is noticed from flagleaf to heading at 60° and 75° view zenith angle. Similarly, the temporal fall in DOP was significant in blue region from flagleaf to heading, whereas the same occured from jointing to flagleaf transition in the infrared region. However, looking at the wavelength x view zenith interactions it is clear that the 75° view zenith in the blue region and 45° view zenith for the infrared region significantly influenced the polarization measurements and therefore have to the respectively preferred to 60° and 30° view zenith angles.

Though it was noticed from Table 1 that the multiple interaction effect (St x WL x Ze) was non-significant statistically, Table 2 reveals considerable drop in DOP from flagleaf to heading in the blue region when viewed at 75° and from jointing to flagleaf in the infrared region when viewed at 45° zenith, and thus leads to these factorial combinations being identified as optimum for detection of the crop growth stages in wheat. A physical understanding of this phenomenon is however required yet.

The anlaysis carried out in this paper suggests the adoption of 75° view zenith to detect the flagleaf-heading transition in the blue region and 45° view zenith to detect jointing-flagleaf transition in the infrared region of the electromagnetic spectrum through polarimetric observations on wheat corp.

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