BISTATIC MICROWAVE SCATTERING MEASUREMENT OF CROP (SORGHUM) CHLOROPHYLL AT X-BAND

SUJAY K. SHARAN[**], R.SAO[*], SANJAY K SHARAN[**] and D. SINGH [**]

[*]Department of Zoology, Govt. P.G. {Autonomous} Science College, Seepat Road, Bilaspur (M.P.), India - 495006.

[**]Department of Physics, Govt. P. G. {Autonomous} Science College, Seepat Road, Bilaspur (M.P.), India – 495006, [e-mail: saransujai@hotmail.com]

1. Introduction

Timely and accurate information on agricultural production is of utmost importance for effective management of agricultural economy. Spectral response of a crop is the integrated manifestation of various crop growth factors e.g. plant height, biomass, leaf area index, total chlorophyll content, soil moisture content etc. In a given time domain, the growth and decay of spectral response such as microwave response indicates the crops performance. Spectral data as such or through its relation with biometric parameters are being used for prediction of yield. For this purpose, spectral data acquired through remote sensing techniques are being used on operational basis for major crops namely corns, soybean, paddy, wheat, groundnut, cotton, sorghum etc. Visible or infrared waves used in remote sensing have limitations and potentials of microware remote sensing are also recognized at present. They are used for operational services and require further experimental and theoretical investigations. The objective of remote sensing is also to design space borne microware sensors to sense the target. For this purpose, the knowledge of target characteristics must be known through ground base remote sensing.

The present study is undertaken to observe the effect of total chlorophyll of crop sorghum on microwave scattering at X-band, using indigenous bistatic scatterometer [1]. The growth and health of crop/vegetation depends on various factors, out of which chlorophyll is one of the most important parameter. The absolute and relative concentration of this photosynthetic pigment dictates the photosynthetic potential of the plant. Thus the changes in the concentration of this pigment would relate strongly to the photosynthetic status of the plant and hence the growth. Thus, if the chlorophyll can be estimated accurately by remote sensing techniques the crop health / yield can also be estimated remotely.

In this paper one of the measure crop sorghum (Sudan grass or Sorghum bulgare) was taken for measurement. For this purpose, a crop bed of 5m X 5m was specially prepared. The field was artificially irrigated at every 25 days. The angular and polarization effect of sorghum chlorophyll on X-band has been measured at regular interval of 10 days. Linear regression analysis of the observed data was carried out and coefficient of correlation (r), coefficient of determination (r^2), standard error (SE) and standard error of estimate (SEE) have been computed. These data can be helpful for making algorithms for air borne or space borne data.

2. Theoretical approach

The dielectric properties of the target are the principal determinants of the microwave scattering. As the total chlorophyll (TC) of the crop (Sorghum) varies, the scattering coefficient also varies. A linear regression analysis is carried out for computing various regression parameters, in which scattering coefficient (σ^0) has been taken as dependent variable on the TC, following empirical model is proposed for predicting σ^0

$$\sigma^0(\theta) = TC \times \{d\sigma^0(\theta)/d\,TC\} + K \qquad \text{-------------- (1)}$$

Where, $\{d\sigma^0(\theta)/d\,TC\}$ is sensitivity of scattering coefficient on total chlorophyll and K is a constant which depends upon system parameters e.g. frequency, polarization etc.and target geometry i.e. stack size of leaves, type of crops etc. In this model other crop parameters like biomass, crop covered soil moisture, leaf area index etc. have been taken as constant.

3. Result and discussion

Botanically the sorghum is defined as a narrow leaf crop. During our study, it attained a maximum height of around 256 cm. As the crop (Sorghum) leaves were narrow in shape but long in size and at normal crop density. From Fig. 1, it is observed that value of total chlorophyll (TC) reaches its peak values around 35 days after sowing and decreases slowly till the mature stage. The chlorophyll of sorghum obtained by the method given by [2]. This type of variation of total chlorophyll gives good results for scattering measurements.

The variation of total chlorophyll with scattering coefficient has been shown in Fig. 2. As discussed earlier total chlorophyll increased at early phase i.e. before flowering stage, and there after decreases up to mature stage. σ^0 increases as the chlorophyll content increases for both like polarizations (i.e. HH- and VV-pol.). Table I shows the regression results of scattering coefficient Vs. total chlorophyll for different angle of incidence. From table I. and Fig. 2, it is clearly observe that σ^0 increases for both like polarization but the slope of σ^0 on TC is slightly higher for VV-pol than HH-pol. Therefore, it can be said that VV-pol is better for sensing the sorghum total chlorophyll. It is observed in the same table that the value of coefficient of correlation (r) varies from 0.3613 and 0.6657 for HH-pol and 0.1526 to 0.7330 for VV-pol. For both like polarization maximum value of r is at 40^0 incidence angle. Therefore, it can be said that, the most appropriate angle of incidence to observe the effect of total chlorophyll (TC) of crop sorghum on X-band is near to 40^0 incidence angle. The value of r^2 tells about the dependence of

σ^0 on TC. It is observed that the value of r^2 is 0.4432 and 0.5373 for HH-and VV-pol respectively at an angle of 40^0. The value of r^2 is higher for VV-pol than HH-pol. It means that VV-pol. shows better dependence of σ^0 on sorghum TC than HH-pol. Therefore, VV-pol should be preferred for observing the effect of total chlorophyll on σ^0. The value of r^2 is low at lower angles of incidence to observe TC. It may be due to when crop TC is small and crop height is also small than crop covered soil moisture effect is more dominant.

The value of standard error (SE) tells about unreliability of samples. In the same table, standard error decreases with increase of angle of incidence but minimum value of SE is 4.55 X 10^{-4} and 0.94 X 10^{-4} for HH-and VV-pol respectively. The value of standard error is lower for VV-pol than HH-pol. The value of standard error of estimate (SEE) tells about the dispersion of near about the average line. The value of SEE is also minimum at 40^0 angle of incidence i.e. 0.0472 and 0.0028 for HH- and VV-pol. respectively. The value of SEE is lower for VV-pol that HH-pol. This reinforces the earlier statement that VV-pol shows better effect than HH-pol. The empirical relations for observing σ^0 on TC at 40^0 incidence angle at X-band are following

σ^0_{HH} = -16.8 TC + 0.4247 ----------------------(2)

σ^0_{VV} = -13.2 TC + 0.8128 -----------------------(3)

4. Conclusion

The dielectric property and geometry of the crop (sorghum) itself along with its distribution influence the scattering of microwave with crop (sorghum) total chlorophyll in the ambient medium. From the regression result it can be said that for observing the effect of total chlorophyll on scattering coefficient, VV-pol is better than HH-pol. The best suitable angle of incidence to observe the effect of total chlorophyll on scattering coefficient is about 40^0 incidence angle. At lower angles the soil moisture effects becomes more dominant and at higher angle of incidence other vegetation effects become more significant.

REFERENCES-

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[2] L.N. Kakati and R. S. Yadava, "Seasonal changes in chlorophyll and caretenoids contents in a grass land of ecosystem at Imphal". Tropical Ecology, vol 31(1), pp82-88, 1990.

Table I: - Linear regression result of scattering coefficient Vs total chlorophyll for different angle of incidence (θ) at X-band

Slope	r^2	r	SEE	SE	Pol	Angle
0. 069	0.1306	0.3613	0.0926	8.82	HH	20
0. 189	0.3904	0.6248	0.0934	8.95	HH	30
0. 349	0.4432	0.6657	0.0472	4.55	HH	40
0. 239	0.2704	0.5200	0.1421	14.84	HH	50
0. 146	0.4157	0.6447	0.1172	12.53	HH	60
0. 120	0.4208	0.6487	0.606	6.69	HH	70
0. 050	0.0234	0.1529	0.0117	1.16	VV	20
0. 132	0.4049	0.6363	0.0152	1.43	VV	30
0. 674	0.5373	0.7330	0.0028	0.94	VV	40
0. 120	0.2955	0.5436	0.0122	1.24	VV	50
0. 121	0.4154	0.6445	0.0098	9.47	VV	60
0. 036	0.0233	0.1526	0.0094	8.99	VV	70

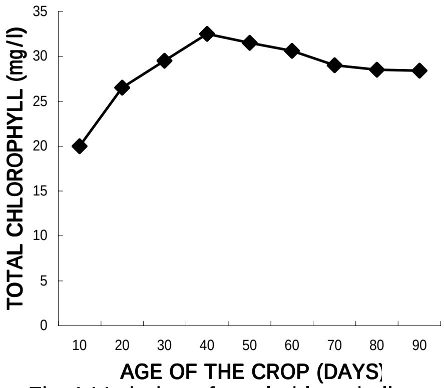

Fig. 1 Variation of total chlorophyll for crop Sorghum with age of the crop

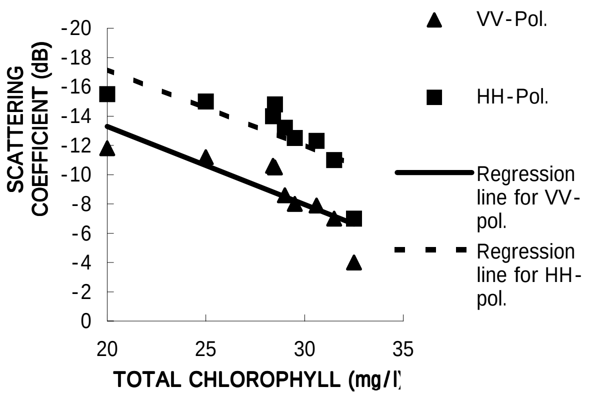

Fig.2. Variation of scattering coefficient with total chlorophyll at the 40 degree incidence angle for HH- and VV-pol. at X-band