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GROUND-BASED MEASUREMENTS OF SPECTRAL CHARACTERISTICS OF CROPS AT DIFFERENT GROWTH STAGES

1. In this study, an attempt is made to show the variation of spectral characteristics and some vegetative indices with growth stages of gram, linseed, wheat and safflower. It may give a guideline to explore the possibility to use satellite remote sensing data for identification of these crops which is necessary to estimate ultimate production (Kamat *et al.* 1983).

2. Plots of size 1.5 × 3m, having crops, gram, linseed, wheat and safflower were selected for observations in the campus of the college of Agriculture, Pune. During November 1991 gram (N-5a) was sown on 19 Linseed (55) on 20, Wheat (HCS-9) and safflower (S-4) on 18. Their growth sequences are given in Table 1. The observations were started from 30 November. All the crops were in the early stage of vegetative phase. No special treatments were given to the crops at any stage.

2.1. A hand-held multiband Ground Truth Radiometer (GTR) manufactured by M/s Optomech Engineers Private Limited, Hyderabad was used to measure the radiance by holding it at nearly 1 m height above the crop canopy by hand. Eight spectral bands having first four identical to four bands of Landsat and next four identical to four bands of IRS satellites were available in the instrument. The specifications of the instrument and wavelength bands supplied by the manufacturer are given in Tables 2 & 3 respectively. No further calibration of the radiometer was done by us. The ground area covered by 15° field of view of the sensor is approximately of 13 cm radius.

The observations were taken between 1100 & 1500 hrs once in a week throughout the growing season of the crops on days with clear sky. While taking the readings, the sun was never above the object as in mid-noon to avoid shadow effect of the leaves. The first observation was taken over a calibrated plate coated with Barium Sulphate ($BaSO_4$). To reduce the error caused by positioning the radiometer, spectral measurements were made over five points in each plot and the mean of these readings for each band was calculated (Dubey *et al.* 1992). The difference at third place of decimal (*i.e.*, less than 1%) were found in radiance values measured at five points in each plot. The second observation over calibrated plate was taken after observations in each field.

3. The reflectance over crop canopies was calculated by dividing mean crop radiance by average of both calibration plate readings. Variation in the spectral responses between red and near infrared bands are minimised because of their proximity and similar atmospheric absorption/transmission properties. The spectral reflectance of main growth stages of gram, linseed, wheat and safflower are plotted in Fig. 1.

The difference between reflectance in red and infrared bands is independent of varying solar irradiance and soil type and so may provide better estimate of biomass parameter (Tucker 1977). This idea has been the basis of several vegetation indices based on waveband ratios. Some of the better known are Ratio Vegetation Index (RVI), Normalised Difference Vegetation Index (NDVI) and Green Vegetation Index (GVI).

RVI and NDVI are defined as follows :

$$RVI = IR/R$$

$$NDVI = (IR - R)/(IR + R)$$

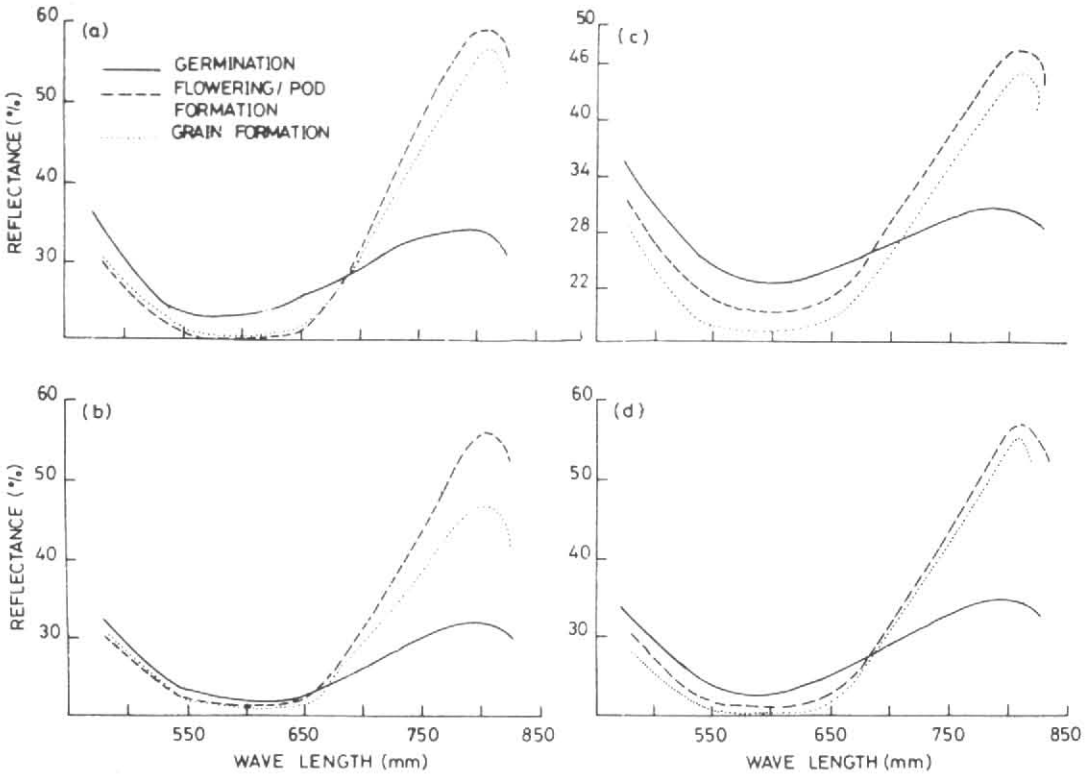
where, IR and R denote the reflectance in near infrared region and red region respectively. The mean of reflectances in band 4 (B_4) and band 8 (B_8) is taken for IR and that of band 3 (B_3) and band 7, (B_7) is taken for R.

Green vegetation index (GVI) is defined by the formula :

$$GVI = -0.29B_1 - 0.56B_2 + 0.60B_3 + 0.49B_4$$

where, the reflectances in bands 1, 2, 3 and 4 of the radiometer are taken as consecutive four MSS (Multispectral Spectral Scanner) bands of Landsat (Kauth and Thomas 1976). These indices were calculated for every observation and plotted in Figs. 2 (a-d) with days after sowing (DAS) to find out the sensitiveness of a specific index of the growth stages of different crops.

4. The variation of reflectance with wavelengths at mainly three growth stages (*i.e.*, Early growth, flower/pod, grain formation) of gram, linseed, wheat and safflower are depicted in Figs. 1 (a-d) to show the inter-stage difference in individual crop. The similar work was done, for wheat, gram and mustard at IARI, New Delhi by Kamat *et al.* (1983) with the objective to integrate aerospace remote sensing technology. It was found that spectral parameters can be used for estimating the crop



Figs. 1 (a-d). Variation of reflectance with wavelength at different growth stages of (a) gram (b) linseed (c) wheat and (d) safflower

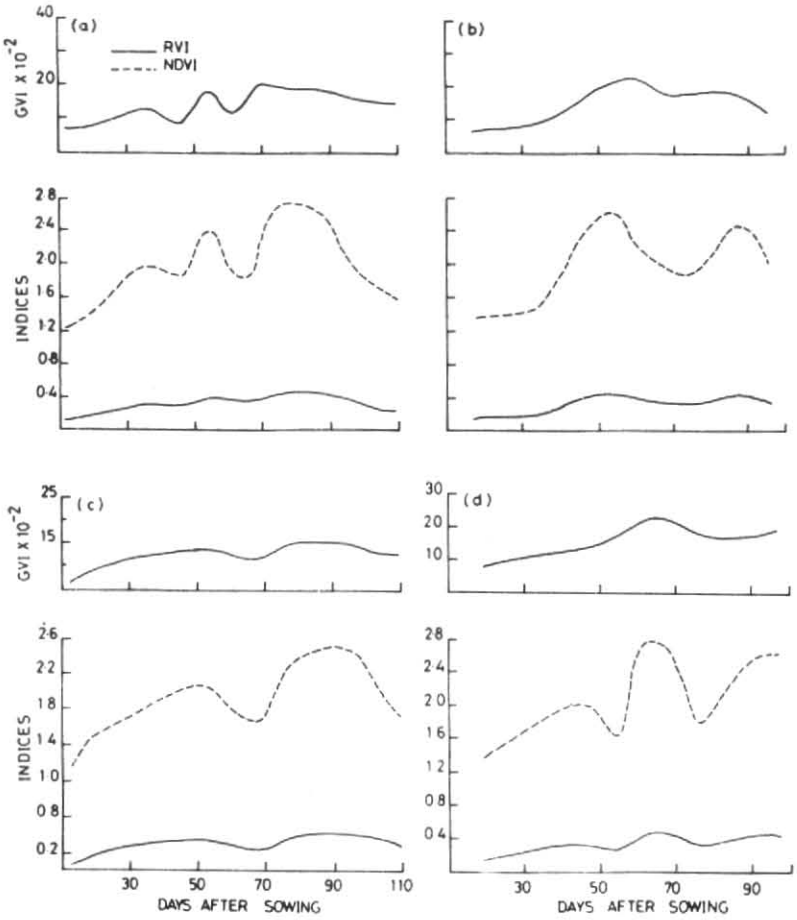
TABLE 1

Growth sequences of various crops

Crop	Variety	Date of sowing	Date of germination	Date of flowering/ pod formation	Date of grain formation	Date of harvest
Wheat	HCS-a	18 Nov 1991	24 Nov 1991	17 Jan 1992	20 Feb 1992	30 Mar 1992
Gram	N-59	19 Nov 1991	26 Nov 1991	10 Jan 1992 (F) 31 Jan 1992 (P)	24 Jan 1992	2 Apr 1992
Linseed	55	20 Nov 1991	26 Nov 1991	13 Jan 1992 (F) 31 Jan 1992 (P)	14 Feb 1992	27 Feb 1992
Safflower	S-4	18 Nov 1991	25 Nov 1991	14 Feb 1992	20 Feb 1992	01 Apr 1992

growth variables. In red region, at the early growth stage gram, wheat and safflower crops have higher and well seperable pattern from other stages while linseed has reflectance almost equal to that of other stages. It may be due to less biomass density and hence more red reflectance than in other crops. It gives the clue that the False Colour Composite (FCC) imagery of a satellite having high spatial and radiometric resolutions may be helpful in identifying early growth stage of gram, wheat and safflower but not linseed.

In the Infrared region, the relative inter-stage differences in the curves of one crop is not as in other crop. The grain formation stages in every crop starts with senescence so the reflectances in infrared region are lower than the pod/flowering stages though very much higher than those in early growth stages. It shows the pod/flowering stage is the most critical stage for identification of any crop by remote sensing technique. Linseed can be well distinguished during its early growth, pod formation and grain formation stages in IR band. It is due to



Figs. 2. (a-d) Variation of various vegetation indices with days after sowing (DAS) of (a) gram (b) linseed (c) wheat an l (d) safflower

the higher sensitiveness of these stages in IR band. Little difference in biomass characteristic in these stages causes appreciable changes in reflectance in IR but not in red band.

There is very little difference between red and IR reflectance in flowering and grain formation stages of safflower. Wheat can be recognised well in red and IR bands in all the growth phases but these differences are more pronounced in IR band.

If we look at the inter-crop variation in reflectances at different growth states, the patterns are similar without any appreciable difference in red and infrared region.

The utility of various spectral vegetation indices, *viz.*, GVI, RVI, and NDVI can be seen in Figs. 2 (a-d). The general trend of GVI variation with DAS in all the crops is almost similar. It increases with the growth of the crops, reaches maximum after 60-70 days of sowing except in case of Linseed where maximum reaches after 50-60 days. Afterwards it starts decreasing. RVI is seen to be more sensitive index. It fluctuates with the growth stages of the crop. It increases up to 50 days in case of wheat and linseed but increases up to 40 days in case of gram and safflower. Earhead in case of wheat and flowering in case of linseed started after 50 days of sowing date. Gram started flowering but safflower was in full vegetative phase after 40 days from sowing date. RVI starts falling after 60-70 days in case of linseed, safflower and wheat but gram shows peak around 55 days and then 70 days with fall in between and then gradual falling after 70 days. GVI increases with growth and reaches to maximum at around 70 days and then falls due to highest greenness at the end of flowering/pod formation stage in all the crops.

RVI shows very high fluctuation between 50-60 days after sowing in all the crops. After 90 days it falls rapidly except safflower, where it starts increasing again. Thus sharp demarcation in maturity phases may not be possible in safflower but possible in linseed, gram and wheat. The range of variation

TABLE 2

Specifications of ground truth radiometer

Field of view	15° ± 2°
Output	On 3½ digit digital-panel-meter
Band selection	By rotating the filter wheel
Dynamic range	0.1×10^{-6} to 30×10^{-3} watts/cm^2 – Sr-u
Absolute accuracy	± 5%

TABLE 3

Filter details for multiband ground truth radiometer

Band No.	Central wavelength of the filter (um)	Band width of the filter (um)	Spectral range of satellite bands (um)
1	0.4830	0.0564	0.45 — 0.52*
2	0.5442	0.0854	0.52 — 0.60*
3	0.6555	0.0610	0.63 — 0.69*
4	0.8189	0.1484	0.76 — 0.90*
5	0.4798	0.0757	0.45 — 0.52+
6	0.5408	0.0816	0.52 — 0.59+
7	0.6557	0.0625	0.62 — 0.68+
8	0.8122	0.0871	0.77 — 0.86+

* Landsat satellite + IRS satellite

in RVI is due to fluctuation in flowering to grain formation stage is same in case of all the crops. The similar fluctuations may be due to soil and weather factors. NDVI is a normalised index. It suppresses the effects of topography and solar rays reaching the ground. Thus, the deep fluctuations in GVI and RVI curves are mostly suppressed in NDVI curve and hence it looks very smooth. It shows that the RVI curves may be very useful for crop identification.

5. Based on the above studies and discussion, the following conclusions can be drawn :

(*i*) The early growth stages of gram, wheat and safflower show well-separable patterns in red region of spectral reflectance curves than in the other growth stages.

(*ii*) The most important stage for identification of crops is flowering/pod formation stage.

(*iii*) The IR band is more sensitive to different growth stages of linseed and wheat crop.

(*iv*) Among all spectral vegetation indices, RVI is most sensitive to phenological changes in crops.

(*v*) The sharp demarcation in maturity phase may not be possible in safflower but possible in linseed, gram and wheat.

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