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Effect of Incident radiation on spectral response of *Rabi* crops

SK Thakur, Rishi Pathak, Ajay Ahirwar and RK Nema

Abstract
Spectral response of any surface on earth is determined by measuring reflected energy from that surface and comparing with the incident radiation measured on a standard plate coated with barium sulphate. It has been observed that percentage reflectance in different crops has a defined trend from sowing to harvesting in normal weather conditions. However this trend is affected if the incident light radiations vary significantly. The present study was conducted to establish the reflectance pattern in different *rabi* crops and to relate the response obtained with the available ground information with variation of differernt incident radiation. Optimum time span was identified for distinguishing the different rabi crops namely Mustard, Potato, Onion, Wheat, Marigold, Vegetable Pea, Chickpea, Garlic and Berseem using hand held spectro radiometer based on their spectral signatures at Research farm under the department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidayalaya, Jabalpur, during 2009-10. This area lies in the central part of Jabalpur district, Madhya Pradesh. It has a typical subtropical climate with hot dry summers and cool dry winters The experimental plots during both the seasons have sandy – clay soil, with normal soil reaction and electrical conductivity, low in organic carbon and available nitrogen and medium in available phosphorus and potassium. The difference of average reflectance is increasing from Band 1 (BLUE) to Band 4 (NIR) during the crop growth from 66 to 130 DAS. Variation in incident energy during the growth period and its effect on reflectance was studied for field and vegetable crops. The results are useful to plan for accepting or discarding the recorded observation for further analyses.

Keywords: Remote sensing, electromagnetic radiation, spectral response, spectral signature

1. Introduction
Remote sensing has proven to be a powerful tool for assessing the identify, characteristics, and growth potential of most kind of vegetative matter at several levels (from biomes to individual plants). Vegetation behaviour depends on the nature of the vegetation itself, its interaction with solar radiation and other climate factor, and the availability of the chemical nutrients and water between the host medium (usually soil or water in the marine environments). Because many remote sensing devices operate in the green, red and near infrared regions of the electromagnetic spectrum they can discriminate radiation absorption and reflectance of vegetation. Reflectance behaviour throughout the growing season may open different aspects for discriminating these growth stages and also irrigation, nutritional and other aspects. Among important factor changing spectral response of crop are cultural practices like fertilizer, irrigation, planting practices, planting date, plant population etc. Any deviation in spectral response are the result of physiological changes in the plants themselves, arising out of changes in the spectral properties of plants and changes in the spectral properties of plant parts and changes in canopy growth including the orientation of plant parts, number and size of leave or other plant parts and amount of soil visible through the canopy. Plant nitrogen content and canopy deficiencies have been related to reflectance measurements in the green, red and near infrared spectrum. The response also varies with plant growth since sowing or transplanting.
This study was conducted to establish the reflectance pattern of different rabi crops and to relate the response obtained with the available ground information. It covers the area of Research farm under the Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur. The boundary and field numbers are digitized manually using ground information through field visit.

The crops of different varieties grown in the study area are Mustard (Terri Uttam), Potato (Khufri Sinduri), Onion (Pusa Red), Wheat (JW 273), Marigold (African Giant), Vegetable Pea (Arkel), Chickpea (JG 322), Garlic (G 41) and Berseem (JB 5). The observations were taken from 21st Jan to 7 April 2010 till the harvest of the crops.

Remote Sensing has proved to be an ideal data set for making crop classification. Typical spectral reflectance of a crop shows absorption due to pigments in visible region (0.4 to 0.7 µm), high reflectance of a crop in the near infrared region because of internal cellular structure of the leaves, and absorption at 1.45 µm, 1.95 µm and 2.6 µm spectral bands due to water content (Chandra and Ghosh, 2007) [1].

It has been found that the knowledge based classification is better than the other methods like maximum likelihood classifier. Crop data of preceding years, stored in a geographical information system (GIS) were used as ancillary data. Along with it the knowledge about crop succession was used for better results. The accuracy of the knowledge-based classification was found 6 to 20 percent better as compared with a maximum likelihood classification on the basis of the spectral class discrimination. (Janssen and Middelkoop, 1992) [4].

The spectral reflectance of a vegetation canopy will differ from the reflectance of individual plant leaves due to variations in the leaf area and orientation, illumination angle, shadows background surfaces such as soil and the presence of multiple leaf layers reported by Colwell, (1974) [2] and the plant canopy light reflectance measurements have been used to characterize the spectral characteristics of plant species and aerial photography and videography have proven useful for detecting plant species on rangelands found by Everitt *et al.* (1986) [3]. McCune B, 2002 [5].

2. Materials and Methods

Jabalpur belongs to Kymore plateau and Satpura hills agro-climatic zones IV of M.P. which is earlier known as Rice-Wheat zone. It has a typical subtropical climate with hot dry summer and cool dry winters. Temperature extremes vary between the minimum of 4 ºC during December or January months to the maximum of 45 ºC in May or June. Average annual precipitation is 1354 mm which is concentrated mostly between mid June to mid September with scattered winter rains during late December and January months.

Spectro radiometer is used for taking spectral reflectance of different rabi crops and soil at their various growth stages. India has designed and developed four band spectro radiometer. The four bands operates in the invisible and near infra red region (i.e. from 0.4 nm to 0.9 nm) to meet these requirements. The instrument is useful for quantitative measurements of visible and near IR radiations. For interpretation of remote sensing data was also collected. Each plot was constantly observed through spectro radiometer for spectral signatures.

The optical head is mounted in such a way that incident radiations are allowed to fall on the lens of the optical head. Spectral band select or selects band out of the four preselected spectral bands through range selection to ensure proper measurement accuracy and offset adjustment to nullify initial radiation conditions and it is the only control mounted at the rear panel of the optical head. The output corresponding to the input radiation level at the selected spectral band is observed on the display unit. This output is in the units of W/cm^2 –Sr-micron. Then it is multiplied by a decoder factor indicated on the range select control. Ground truth radiometer, calibration plate is provided along with the unit. This plate coated with $BaSO_4$, it reflects 100% reading obtained from GTR calibration plate, observation through spectro radiometer was taken during the critical stage and observed the data to the centralized point of experimental plots is calculated.

3. Results and Discussion

Spectral reflectance was measured during sowing to harvesting of different Rabi crops during the year 2009-10. This chapter deals with the results obtained after analysis of observations through the spectro radiometer and to interpretate these data. It also presents the acceptability of the results and their utility for future work.

The study area consist of a Experimental plots having nine crops namely as Mustard (Terri Uttam), Potato (Khufri Sinduri), Onion(Pusa Red), Wheat (JW 273), Marigold(African Giant), Vegetable Pea (Arkel), Chickpea (JG 322), Garlic (G 41) and Berseem (JB 5), For interpretation of Remote Sensing data and spectral signature other subsidiary data was also collected. Each plot was regularly observed through hand held radiometer for the spectral signature of crops. Daily climatic data namely maximum and minimum temperature, maximum and minimum relative humidity, wind velocity, sunshine hours, rainfall and weather (cloud condition) were collected for 1st Nov. 2009 to 31st March 2010 from department of Agrometeoroloy & Physics CAE, Jabalpur.

3.1 Spectral response of different crops

The energy reflectance of crop and soil with respect to calibration plate was measured in band1 (0.4-0.5µm), band2 (0.5-0.6µm), band3 (0.6-0.7µm) and band4 (0.7-1.1µm) using hand held spectro radiometer. The observation of plate, crop and soil through hand held spectro radiometer were taken at different interval till the harvesting of crop. The energy reflectance of Mustard (Terri Uttam), Potato (Khufri Sinduri), Onion(Pusa Red), Wheat (JW 273), Marigold(African Giant), Vegetable Pea (Arkel), Chickpea (JG 322), Garlic (G 41) and Berseem (JB 5) were recorded from the experimental plots.

Table 1: Average reflectance of mustard crop.

DAS	B1	B2	B3	B4
86	66.1	72.3	72.4	76.1
93	60.9	66.6	75.6	74.7
101	71.2	64.4	63.8	69.9

Table 2: Average reflectance of potato crop.

DAS	B1	B2	B3	B4
86	78.8	82.3	84.6	86.0
93	71.9	74.9	79.2	88.5
101	77.1	82.6	82.6	89.7

Table 3: Average reflectance of onion crop.

DAS	B1	B2	B3	B4
66	75	69.9	70.4	78.2
81	73.9	64.1	64.9	68.3
87	72.1	79.1	72.0	70.6

Table 4: Average reflectance of wheat crop.

DAS	B1	B2	B3	B4
66	70.2	78.5	79.2	82.6
73	69.2	73.7	77.8	83.1
81	79.2	68.7	82.1	84.2
110	79.5	83.9	83.3	89.2
117	73.6	81.0	80.4	87.5
130	79.0	76.5	75.6	85.5

Table 5: Average reflectance of marigold crop.

DAS	B1	B2	B3	B4
66	83.7	85.1	76.5	78.5
73	79.7	81.7	87.9	89.1
81	81.1	80.0	77.1	83.0
110	66.0	81.3	71.7	82.5
117	72.3	70.1	80.6	87.8

Table 6: Average reflectance of vegetable pea crop.

DAS	B1	B2	B3	B4
86	90.5	80.1	77.7	84.0
93	67.9	60.8	61.8	63.1

Table 7: Average reflectance of chickpea crop.

DAS	B1	B2	B3	B4
66	75.6	57.5	80.5	80.5
73	61.9	52.2	52.7	52.3
81	69.0	71.4	64.1	57.4

Table 8: Average reflectance of garlic crop.

DAS	B1	B2	B3	B4
86	70.2	61.1	73.4	66.2
93	44.2	31.3	37.6	40.7
101	56.6	50.9	58.9	53.2

Table 9: Average reflectance of berseem crop.

DAS	B1	B2	B3	B4
66	79.4	66.8	74.2	78.3
73	84.6	80.3	80.0	79.4
81	73.6	86.8	88.9	87.7
93	83.8	67.1	83.2	89.1
106	84.8	96.1	89.9	92.0
119	44.7	46.2	43.8	43.1

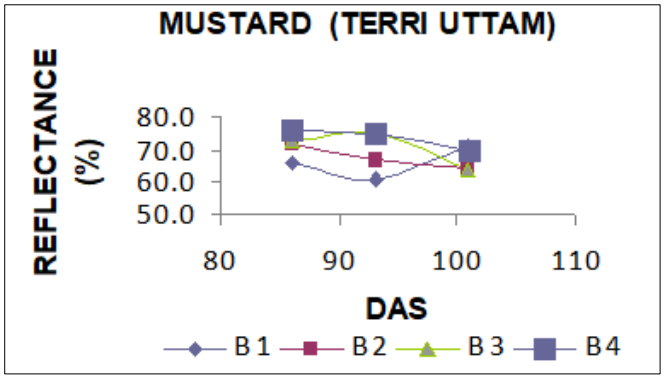

Fig 1: Average reflectance of mustard crop.

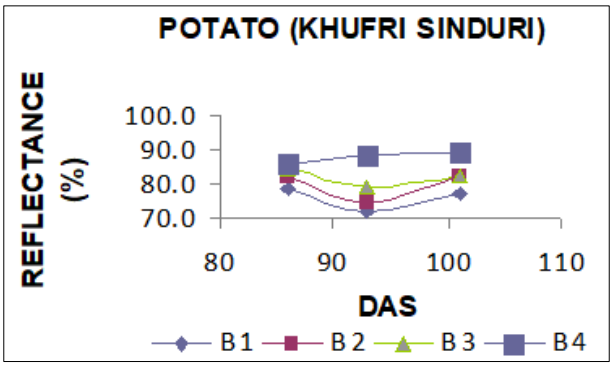

Fig 2: Average reflectance of potato crop.

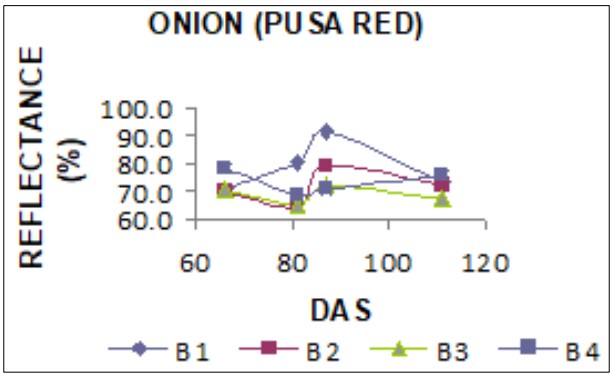

Fig 3: Average reflectance of onion crop.

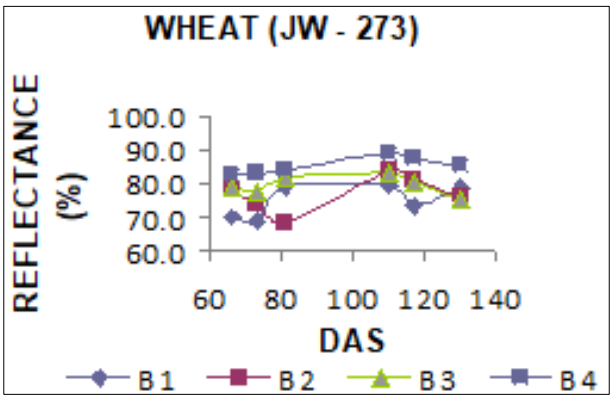

Fig 4: Average reflectance of wheat crop.

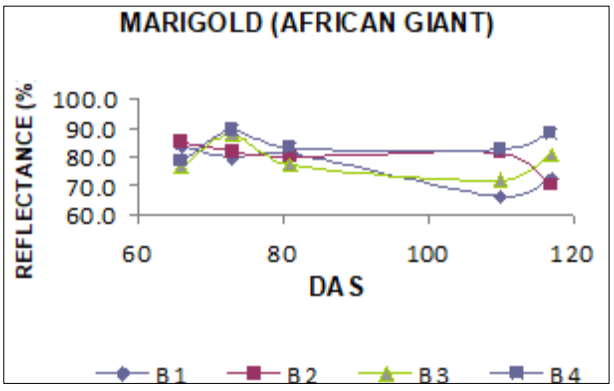

Fig 5: Average reflectance of marigold crop

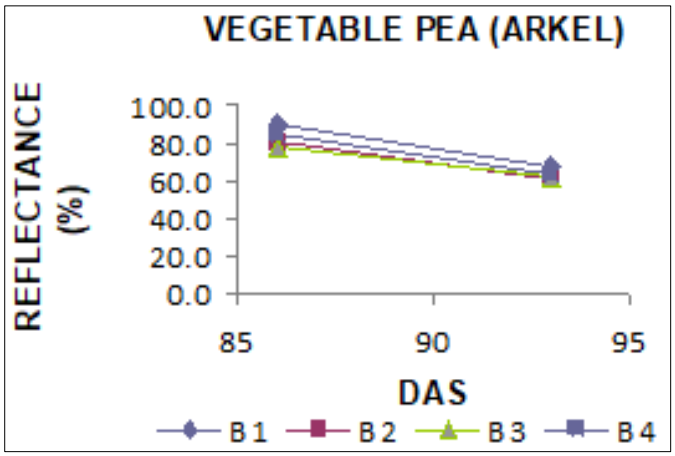

Fig 6: Average reflectance of vegetable crop.

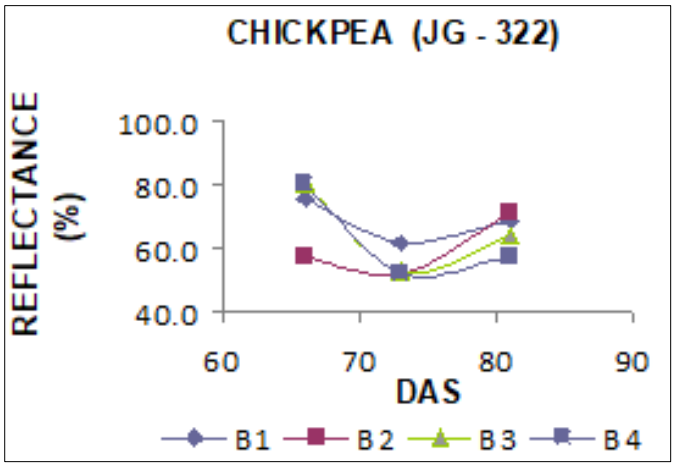

Fig 7: Average reflectance of chickpea crop

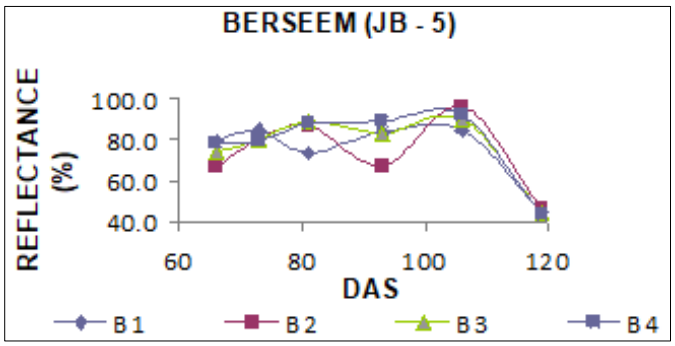

Fig 8: Average reflectance of berseem crop.

The observation recorded on reflectance of mustard crop at various growth stages are presented in Table 1. The readings were taken from 21st Jan to 26 Feb 2010 till the harvest of the crops. There were three plots for each replication with four replications, average reflectance of four different bands are depicted in table 1. In general the peak reflectance occurred on 93rd days after sowing. The average reflectance of mustard crop in all four bands i.e., 76.1 in fourth band was found maximum at 86th DAS and decreases with more no. of days i.e., 69.9 at 101 DAS. To understand the variation in reflectance in each band the observation plotted with respect to days after sowing are depicted in Fig 1. While in case of potato the Table 2 presents the average reflectance of Potato crop. It is increasing with no of days of sowing of crop. In all four bands NIR band gives the maximum energy in every stages of potato crop. There is a significant increase in reflectance in each replication when compared in different bands. There was no significant difference in reflectance with respect to DAS in band 4. Figure 4.4 indicates that there is little increase or decrease of reflectance with respect to days after sowing. However the average reflectance crossing the 70% line in all the four bands. Another crop onion, the observations taken from 21st to 28 March 2010 till the harvest of the crops. The peak reflectance was occurred on 87th DAS in all bands. This can be seen in the Figure 3 that due to greenness of crop it was found that the observations from 66 to 111 DAS in which band 1, band 2 and band 3 showing the peak point at same point i.e., 87 DAS, but the band 4 gives the maximum point at 66th DAS. The reflectance of wheat crop and soil shows similar degree of variation. The average reflectance was maximum in band 4 i.e., 89.2% and minimum reflectance was found 68.7% at 81 DAS. So by these observations it was found that the reflectance is lower at maturity stage of wheat crop. The differences of reflectance in wheat crop shows that all the bands i.e., blue, green, red and near NIR from the maturity stage in greenary condition are found lower and increases with no. of days. In case of Marigold the maximum energy is reflected in 89.1% at 73 days after sowing during 30 Jan 2010 and the lowest percentage of reflectance in 66.0% during 6 March 2010 from 110 DAS. The soil reflectance of these types of crops are minimum as compare both the condition either from calibration plate or crop. The reflectance of marigold is decreasing in maturity stage The maximum energy was found at band 4 (NIR) which is more responsive than the other bands. Due to greeniness colour of marigold crop bands gives the expected results but in case of yellow colour it decreases after due to change in colour of leaf. Similarly in case of vegetable pea and chickpea the figure 6 shows the average reflectance of marigold crop on 86th, 93rd and 101th DAS. There were four plots with vegetable pea. First observation was taken the incident and reflected energy is maximum on 21 Jan 2010 i.e., 90.5% in band 1 at 86th DAS and minimum in band 2 i.e., 60.5% at 93rd DAS. The first observation shows the energy reflectance of Vegetable Pea is more along with incident radiation and in chickpea, it was found that at every stages of crop the NIR band are more responsive than the other three bands. Finally the garlic and Berseem crop, in garlic the maximum energy was found at band 3 (Red) which is more responsive than the other bands. Due to greenness colour of garlic crop bands gives the expected results and it decreases after due to change in colour of leaf and dried condition of crop. Berseem crop are most greenery crop so that the reflectance of this crop are found maximum in all bands. Green colour is more responsive in this crop. The maximum average reflectance was found 96.1% band 2 at 106th days which is most responsible for green crop and minimum reflectance i.e., 43.1 in band 4 at 119th days after sowing (NIR) are most responsive for this stage of crop only because in 119th stage of crop the observation from berseem crop are in dried condition so that not good reflectance was found in this condition. It was also found that the dried condition of berseem crop was also given the better results at the final stage of crop.

The results of the experimental plots confirmed the effects of irrigation with water on crop characteristics, such as chlorophyll content, dry biomass and leaf water potential. In turn, changes in crop characteristics resulted in observable

changes in spectral parameters, such as red-edge position, NDVI and leaf water potential, thus suggesting the observed data of these plots are to assess and useful for further analysis.

4. Conclusion

After studying the spectral responses of various rabi crops during January to April it can be concluded that the observation recorded in mid-January has maximum energy incident and reflected. It is capable of giving information of the crop growth and its performance. Percentage reflectance in Band 1 to Band 4 gives more reliable assessment of mustard, potato wheat and marigold.

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