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Reflectance of Natural Vegetation of Western Rajasthan Region in Visible and Near-infrared Spectra

Ravindra Kumar, Nasreen Ansari, Mahesh Chandra Vyas
M.S. Bishnoi and Madhu Singh

Defence Laboratory, Jodhpur – 342 001

ABSTRACT

This paper presents the study of spectral characteristics of natural vegetation of Western Rajasthan region in the visible and the near-infrared regions of the electromagnetic spectrum. The leaves of ten species of natural vegetation normally grow in Western Rajasthan were evaluated for their spectral reflectance in the wavelength range 400-900 nm under normal laboratory conditions. The change in reflectance due to change in physical condition of plants because of wilting has been observed for three consecutive days. To observe the change due to climatic conditions, the measurements have been carried out in two different seasons. The study aims to undertake design of colour schemes for camouflage painting of various military objects.

Keywords: Camouflage, reflectance, natural vegetation, Western Rajasthan

1. INTRODUCTION

Spectral characteristics of vegetation play an important role in various military applications, including camouflage and concealment of military targets by way of blending them with the background. Reflectance from plant canopies is an integral response of various plant structures. Many of the vegetation factors affect energy responses. These can be related to photosynthesis activity, energy balance, water use efficiency, retention of water content and colour effects. Structure of leaves changes from their initial stage to their maturation stage, which, in turn, causes change in reflectance. Plants reaching the late stage of maturity having less chlorophyll have higher response in visible region than plants in their younger stages which have more chlorophyll.

Boyd[1] carried out a survey, using field telespectrophotometer to gather spectral reflectance data of natural terrain elements of Northern Australia. He calculated colour coordinates using these reflectance values.

The reflectance measurements of the leaves of natural cut vegetation of Western Rajasthan region in laboratory conditions were carried out over a period of three days to see the change in reflectance in visible as well as near-infrared (NIR) region (750–900). The reflectance of the leaves has been related to capacity of cut vegetation to retain chlorophyll state and intercellular spaces. Ten species of vegetation in desert region were selected to study their spectral reflectance at three stages: (i) immediately after removal from their parent plants/trees, (ii) on the second day, and

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(iii) on the third day. This exercise was repeated in two seasons and the results of the study have been compiled for August–September 1999 and January–February 2000.

2. EXPERIMENTAL SETUP

2.1 Spectrophotometer

For the measurement of reflectance for the wavelength range 400–900 nm a spectrophotometer was setup in the laboratory having a source of light, monochromator, detector, photometer and X Y recorder. The description/specifications of different parts of the instrument are as under:

- **Source of Light**

The light source is the incandescent lamp. Its specifications are:

Lamp: Tungsten filament lamp

Colour temperature: 2854 K

- **Monochromator**

A monochromator is a device containing a prism or grating which splits white light into a spectrum and isolates only one part of it at different wavelengths. A slit is used to select a small portion of the spectrum to illuminate the sample. Its specifications are:

Make: Kratos Inc. Schoeffel Instruments

Model: GM 252 high intensity quarter meter grating monochromator

Effective aperture ratio: f 3.0

Focal length: 0.25 m

Linear dispersion: 33 A/mm with standard grating

Wavelength range: 180–3000 nm

Scattered light: < 0.35 % at 500 nm.

- **Spectrometer**

The spectrometer used consists of a sample holder and a detector holder. The position of the sample and detector can be adjusted on a circular platform and both the sample and the detector can be adjusted at a particular angle on the circular scale. For these measurements, the sample was placed at 0° and the detector at 45°

- **Detector**

The light coming from monochromator illuminates the sample and the reflected light is collected and allowed to fall on the detector. For reflectance measurement, a photomultiplier tube is used as a detector. Its response is different for different wavelengths. Its specifications are:

Make: RCA

Model: 74-04 1P 22

- **Photometer**

The photomultiplier tube is connected to a photometer on which the photo current is read on a precision analog meter with mirror scale. A ten-turn potentiometer is used for fine adjustment. A vernier provided permits calibration in between the individual sensitivity ranges. Its specifications are:

Make: Schoeffel Instruments

Model: M460 photometer

Line voltage: 240 V AC

Line current: 0.5 A

Frequency: 50 Hz

Sensitivity: 100 pA

Range: 100 μA–100 pA

- **X Y Recorder**

The detector and the photometer are finally connected to a 2000 X Y recorder on which the signals at different wavelengths from the detector are collected and converted into spectral reflectance curves of the colour samples. These curves show the fraction of the light reflected at each wavelength from the colour samples.

2.2 Standardisation

The spectrophotometer setup in the laboratory is a ratio device; therefore a white panel is required

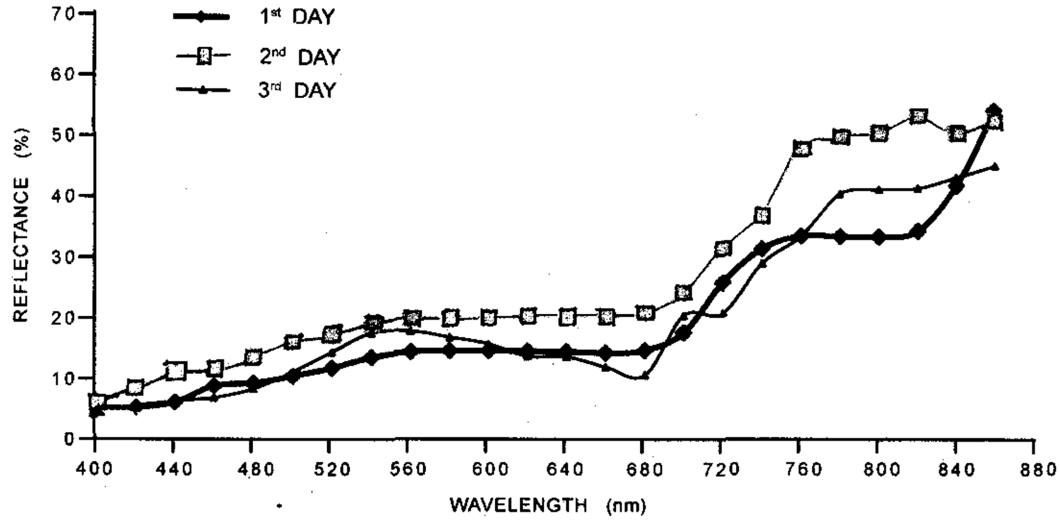

Figure 1. Spectral reflectance of *Tacomella undulata*

as a reflectance standard. A white metallic reference was made by coating barium sulphate, a standard reflectance material having almost 100 per cent reflectance at all wavelengths and on a metallic substrate. To enable its use as a standard reflectance material, the absolute reflectance was determined using Spectrascan 5100 spectrophotometer.

2.3 Methodology

Ten species of the vegetation of Western Rajasthan region were selected for the study. The leaves of these plants were collected and their reflectance measured for three consecutive days to observe change in their reflectance wrt time. The colour of the leaf is affected by gloss, sunlight, self-shading, foliage density, dust and chlorophyll content, etc. The average of the reflectance values at each wavelength, of all the samples were calculated so that a general idea about their colour could be made. To capture the extremes of colour variations due to change of climatic conditions, the measurements were carried out in two phases, during August-September 1999 and January–February 2000. August–September is generally a wet season and January–February is a dry season in terms of average rainfall in the region.

3. RESULTS & DISCUSSIONS

The spectral reflectance plots in the range 400–900 nm are given in Figs 1-10. These plots

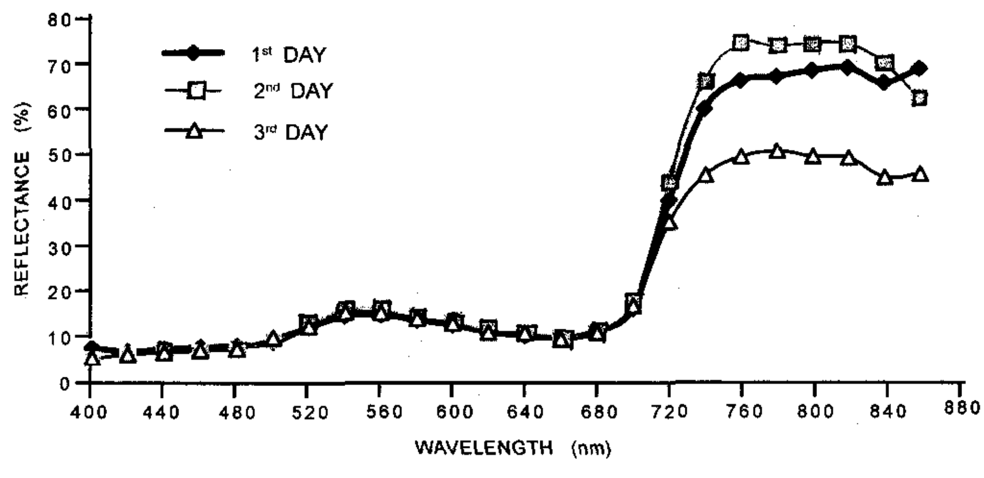

Figure 2. Spectral reflectance of *Prosopis juliflora*

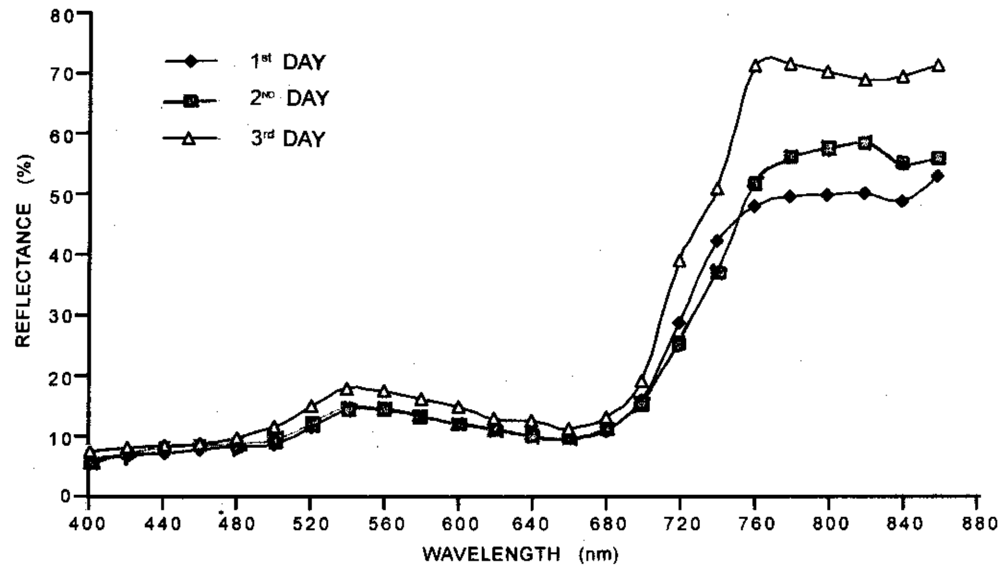

Figure 3. Spectral reflectance of *Salvadora oleiodis*

are showing the spectral reflectance measured for three consecutive days of all the ten species. In visible region, *Melia indica*, *Albizia libbeck* and *Prosopis juliflora* did not show substantial change in their reflectance over the period of three days. It seems that these did not dry up so early and their chlorophyll degradation was low. In *Tecomella undulata, Ficus religiosa, Heloptelia integrifolia* and *Albizia procera*, the change in reflectance from first to second day was very high due to frequent degradation of chlorophyll, but from second to third day, it was negligible. In *Calatropis procera*, *Salvadora olieodis* and *Zizyphus numularia*, the change in reflectance was significant from second to third day.

From the spectral reflectance curves of all the ten species in the range 400–700 nm, it was observed that these show the highest reflectance peaks in green band, i.e., at 550 nm where the reflectance was between 10 per cent to 15 per cent, except in *Tecomella undulata*. All the species were showing strong absorption in blue and red band except *Tecomella undulata*.

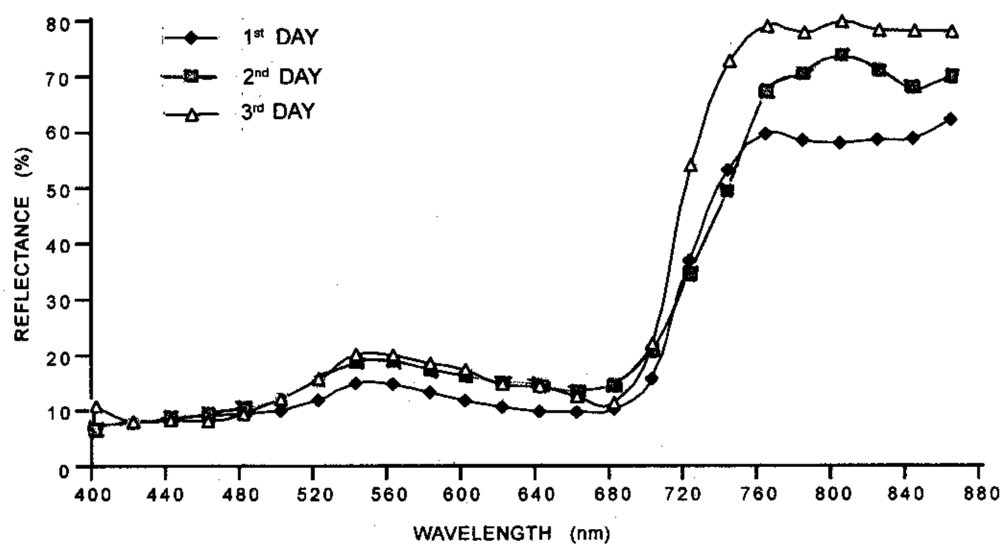

Figure 4. Spectral reflectance of *Alibizia procera*

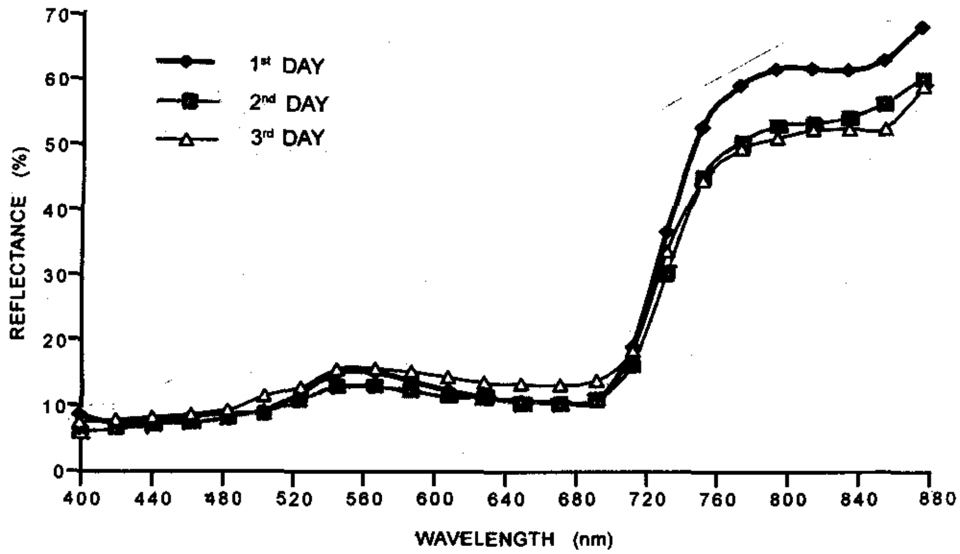

Figure 5. Spectral reflectance of *Melia indica*

The chlorophyll of green leaves usually absorbs 70 per cent to 90 per cent of the light in the blue part (~ 450 nm) and red part (~ 675 nm) of the spectrum[2]. Absorption is the lowest in the wavelength region around 550 nm, where a reflection peak of usually less than 20 per cent occurs from upper leaf surfaces. Low pigment content often results in higher reflectance[3]. The presence of carotenoid and anthocyanin pigments markedly affects light absorptance, and hence reflectance of plant leaves. If the leaves have anthocyanin ortene pigments in ambundance after the chlorophyll has been lost, there may be relatively high reflectance in the red and the near-blue region of the visible spectrum, respectively. The physiological stresses directly affect the reflectance properties of leaves[4]. The most pronounced initial change often occurs in the visible spectral region rather than infrared region. This change is primarily due to the sensitivity of chlorophyll.

In the NIR region, the reflectance is high and absorption is low due to internal leaf structure. Gausman[5,6], *et al.* established quantitative relationship between the reflectance in the NIR

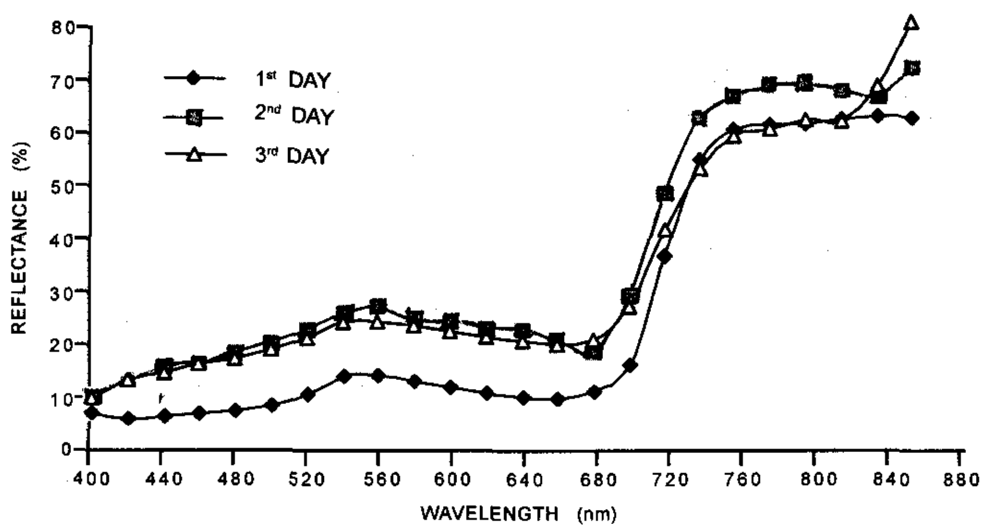

Figure 6. Spectral reflectance of *Ficus religiosa*

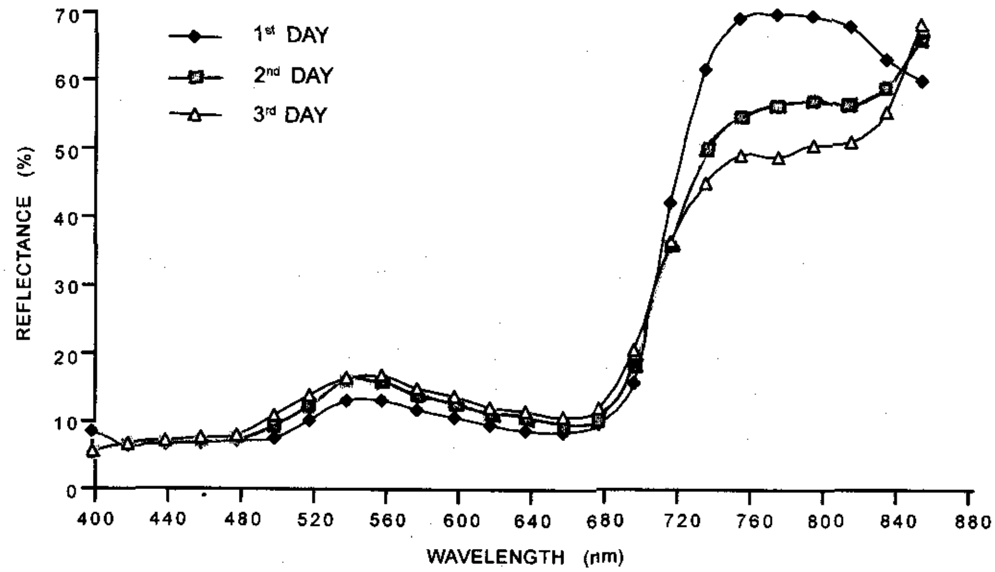

Figure 7. Spectral reflectance of *Zizyphus numularia*

region and the number of intercellular air spaces. Reflectance in the NIR region increases with an increase in the number of air spaces. A spongy leaf compared with a compact leaf has about 5 per cent less reflectance in visible and 15 per cent more reflectance in the NIR region.

In the NIR region (750–900 nm), reflectance for the first day was very high (above 60%) for *Ficus religiosa, Albizia libbeck, Prosopis juliflora, Calatropis procera, Melia indica, Albizia procera* and *Zizyphus numularia*. Reflectance in the NIR region in the above wavelength region was medium for *Heloptelia integrifolia, Salvadora olieodis* (40–50%). Reflectance in the NIR region was very low in the case of *Tecomella undulata* (< 35 per cent). In *Tecomella undulata*, it was observed that the reflectance in the NIR region on the second day increased up to 50 per cent but on the third day, it came down to 40 per cent. The reflectance

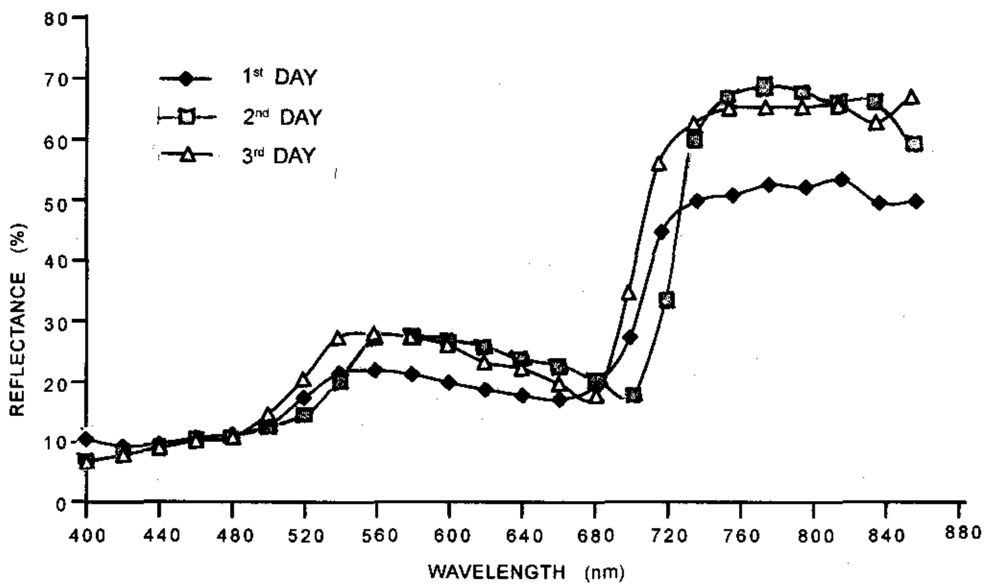

Figure 8. Spectral reflectance of *Heloptelia integrifolia*

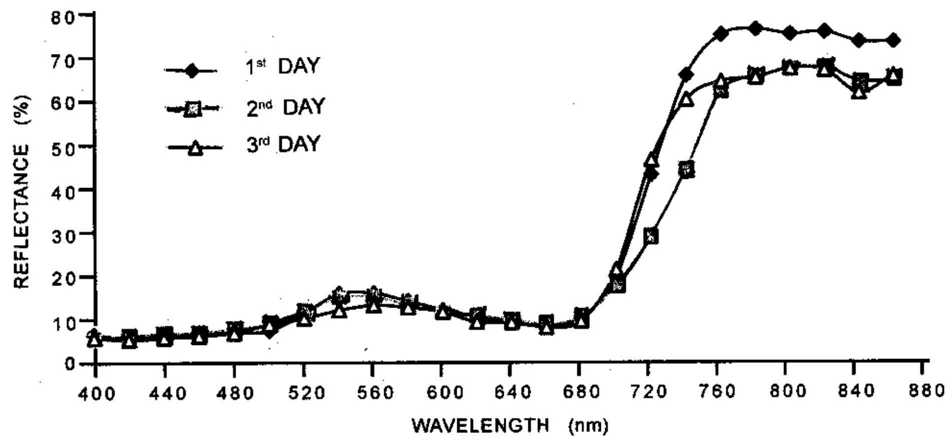

Figure 9. Spectral reflectance of *Albizia libbeck*

in the NIR region was increased for *Salvadora olieodis* when measured on the second and the third day, whereas in *Heloptelia integrifolia,* reflectance in the NIR region was almost constant for the second and the third day but it was significantly high. Increase in reflectance in the NIR region in the species mentioned above, after drying up may be due to contraction of cells and increase in intercellular air spaces. In *Melia indica,* the reflectance in the NIR region of the second day was same as that observed on the first day but it was very high on the third day. It is inferred that drying up of leaves was slow in this species. In *Calatropis procera,* difference in reflectance in the NIR region observed on the first, the second and the third day was very low. This may be due to retention of cell volume, moisture content and slow drying up process, whereas reflectance in *Prosopis juliflora* was very high on the second day compared to the first day and low on the third day compared to the first day. This phenomena has to be investigated further as the same trend had been observed in *Albizia libbeck* and *Zizyphus numularia* also where reflectance in the NIR region on the second and the third day was less than on the first day. It is worthwhile to mention that these species were showing very high reflectance in the NIR region on the first day as mentioned above.

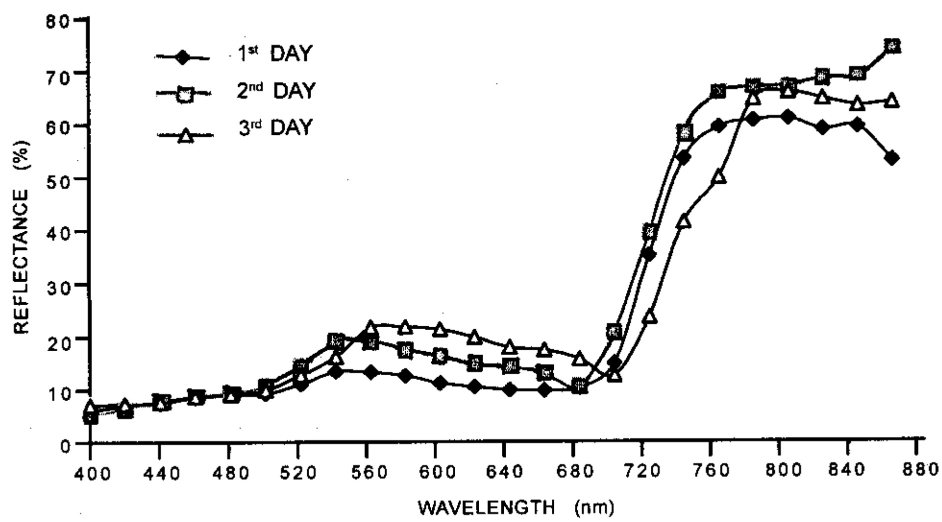

Figure 10. Spectral reflectance of *Calatropis procera*

4. CONCLUSION

The limited number of samples provides only preliminary estimates for the vegetation colour of Western Rajasthan region. A detailed spectral analysis of all the species in various seasons has to be carried out to establish spectral characteristics of desert vegetation in visible and NIR regions. This paper gives a preliminary idea about the spectral nature of desert vegetation of Western Rajasthan region, which can be suitably extended for various military applications, including camouflage and concealment of military targets. For moving equipment, the exact colour matching is not possible and it is therefore necessary to know the range of the vegetation colours, which can suitably match with the surroundings. This study provides sufficient information in terms of spectral reflectance about the range of the vegetation colours most likely found in Western Rajasthan region.

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