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Research Article

Crop Growth Monitoring using Green Seeker Technology - A Case of NARC Field Station in Pothwar Region

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Abstract: The green seeker technology was applied to acquire Normalized Difference Vegetation Index (NDVI) and Red-Near Infrared (NIR) ratio of main crops i.e. wheat, rice and oats grown in the NARC field station, Pothwar region to provide repository for future monitoring of the crops through satellite imaging. The spectral data of different growth stages of the wheat crop indicated NDVI values ranging between 0.1 - 0.88 during Rabi 2006-07 and Rabi 2015-16. The values of wheat and oat crops indicated a similar pattern during Rabi 2015-16, but with slight difference before the heading and near the harvesting stage of the crops. The NDVI values of rice crop grown in the irrigated fields during Kharif 2007 ranged between 0.03 - 0.61. The value was maximum during the heading followed by maturity stage. NDVI values observed in the rainfed fields indicated high variability due to heterogeneous crop cover resulting from variable moisture conditions, fertilizer use, soil type and sowing practices. A detail study needs to be carried out in different agro-ecological regions of the country to collect unique spectral characteristic of different crops and the surrounding land covers to support satellite based crop monitoring and yield forecasting in future.

Keywords: Green seeker, spectral reflectance, vegetation index, crop monitoring, Pothwar

1. INTRODUCTION

The economic base of Pakistan relies on optimum growth and development of the agriculture resource in the country. There is a need to adopt technologies that can lead to effective monitoring and assessment of this resource in advance. Satellite imaging provides a synoptic view of a large earth's surface area for resource monitoring which is by other means difficult to monitor or at times impossible to access. Since chlorophyll, a key indicator of crop physiological status, has strong absorbance peak in the red spectral region, empirical models of predicting chlorophyll status from spectral reflectance are largely based on red spectra [1-4]. Under normal conditions, nitrogen fertilizer influences chlorophyll concentration in green leaves [5]. Image from the green and near infrared (NIR) bands highlight the amount of vegetation and give an indication of plant vigor. Visible and infra-red (IR) wavelength bands (channel) on the satellite multi-spectral sensors allow monitoring conditions like greenness of plants, drought and desertification.

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The differences in leaf color, texture, shape or even how the leaves are attached to plants, determine, how much energy will be reflected absorbed or transmitted. The comparison of the reflectance values at different wavelengths, called a vegetative index, is commonly used to determine plant vigor. The most common vegetative index is the Normalized Difference Vegetation Index (NDVI), the value of which helps identify areas of varying levels of plant vigor within fields on an image. The NDVI data have been used extensively in vegetation monitoring, crop yield assessment and forecasting [6-8]. The index works on the phenomena that growing green plants absorb radiations in visible region and emits infra red radiations. The reflectance of vegetation cover especially the health of crop cover can be determined using the Green Seeker (GS) technology which measures NDVI and Red- NIR ratio of the crop cover.

The studies have shown that seasonal crop growth and development can be monitored using vegetation indices (VI) computed from red and NIR wavelengths e.g. [9-11, 5]. Besides the indicators of crop growth variables, VIs were applied to detect nitrogen stress [12-13]. The magnitude and duration of seasonal VI profiles are directly related to leaf area index (LAI), biomass and percent cover [14]. These parameters are largely influenced by variations in soil fertility, soil moisture, planting date and crop density. The potential yield of a crop is said to be a function of leaf area at the beginning of the reproductive stage and final yield is related to the duration of green LAI assuming the absence of significant stresses during the heading/ filling stages. The highest single date correlations between yield and VIs occur around the booting-heading stage of wheat, which is closely associated with peak seasonal VIs [15]. The challenge remains at the farm level to develop more quantitative in-field yield variation and to deliver them in time to effectively influence crop management decision. The primary focus of this study is to develop a repository of spectral reflectance data of crops using green seeker technology that would help in crops yield estimation through multispectral remote sensing in future.

The study area of National Agricultural Research Centre (NARC) lies within longitudes 73º 6´- 73º 9´ E and latitudes 33º 38´ - 33º 42´ N in Capital territory of Islamabad, Pothwar tract of Pakistan (Fig. 1). It comprises of experimental fields and laboratories over an area of about 565ha along Korang stream downstream of Rawal dam. The climate is sub-humid with mean annual rainfall of about 1216mm (1988-2008 period) recorded at NARC Agro-met. station. Mean monthly maximum temperature ranges between 35-41ºC and mean monthly minimum temperature between 1-25ºC. June is the hottest and January is the coldest month in a year. The soil is deep and varied in type i.e. mainly moderately calcareous clay loam to silty clay loam with good drainage. About 90% area is relatively flat with a general slope of 1% [16]. Major Rabi crops are wheat, oilseed, oats and lentil while Kharif crops are maize, rice and millet. Fodder is usually grown in both the seasons. More often the sowing of various crops especially the winter (Rabi) season crops is delayed due to uncertain and scanty rains prior to sowing of the crops [17].

2. MATERIALS AND METHODS

The Green Seeker instrument equipped with Holland Amber Sensor (Ntech Industries, Ukiah, CA) was used in the cropping fields of Crop Science Institute (CSI) to collect reflectance data of wheat crop during Rabi 2006-2007 and rice crop during Kharif 2007 season (Fig. 2a). This instrument detects electromagnetic bands red and NIR of reflected energy from the material and determines NDVI and bands ratio. The instrument's optical sensor captures and analyzes the light reflectance of plants and the collected data with the sensor can be downloaded to a personal computer in a text format that can be accessed by Microsoft Excel. Later on, a handled green seeker NDVI sensor developed by Trimble's Agriculture Division,USA was used to collect the reflectance data of wheat and oat crops during Rabi 2015-16 (Fig. 2b). Rabi season starts by mid-October in the rainfed areas, but main activity of wheat crop sowing starts from 1st November and continued till 30th November. In some cases when precipitation period delays then late sowing of wheat continues to December.

$$NDVI = (NIR - R) / (NIR + R) \quad (1)$$

Where

NIR = Near Infrared Reflectance band value

R = Red Reflectance band value

The index is described by a value ranges from -1 (usually water) to +1 (strongly vegetative growth). The NIR and R bands of remote sensing data are usually used to determine NDVI for monitoring crop growth and discriminating vegetation vigor in the image. Field data e.g., plant condition, sowing & harvesting dates, input use and GPS coordinates were collected from appropriate locations (hereinafter: "segments") after specific time intervals to detect growth variation. As the crops grown in various fields have variable sowing dates and varieties so a particular crop type and its full growth period is focused in this study. For each plot 3 to 5 different readings were taken each time. The instrument was placed at about 0.7m above the crop canopy while taking the readings.

Green Seeker Technology and Satellite Imaging

The Green seeker instrument detects electromagnetic bands red and NIR of reflected energy from the material and determines NDVI and bands ratio. The central wavelength of the red and NIR channels of most multispectral sensors such as TM, SPOT and MODIS, on the current satellites, position at 640-660 nm and 800-870 nm [5]. The red-NIR could be used to estimate crop nitrogen stress [10-11, 13]. The Green seeker technology coupled with remote sensing imaging can be utilized effectively for identification and assessment of vegetation covers, crop acreage, health and yield in any area. Remote sensing offers great potential for monitoring and assessment of crop acreage and production. If utilized effectively, quantification of accuracy and precision of regional crop rotation and estimation of yield from remote sensing can be achieved. Interpreting the reflectance values at various wavelengths of energy can be used to assess crop health. The relationship between reflected, absorbed and transmitted energy is used to determine spectral signatures of individual land features. Spectral signatures are unique to plant species. Imaging scanners are available with spectral bands throughout the ultra violet (UV), visible, short infrared (SWIR) or near infrared (NIR), and thermal IR range. As the growing plants turn green in color the chlorophyll in the leaves absorbs the red radiation and at the same time increases the infrared reflectance [18]. Vegetation is easily detectable with the use of red and infrared bands i.e. it can be distinguished from soil and water. The high spectral resolution of RS data is useful in identifying distinct crop covers, forest types, grass, shrub lands, etc. accurately.

3. RESULTS AND DISCUSSION

The NDVI data of wheat, rice and oat crops was collected at various growth stages during Rabi 2006-07, Kharif 2007 and Rabi 2015-16 from the NARC research station. The wheat crop (Wafaq2001) was sown in the CSI field on 8-11-2006 and wheat (Pakistan2013) in plot no. C2 on 25-11-2015. Observations were made considering various phenological phases of the crop. When 10% of the selected plants were in certain phase, that particular phase was considered to be started. If 50% of the selected plants displayed a certain phase, that phase was considered to be in full swing. Similarly, 75% occurrence of a certain phase displayed by the selected plants was considered as completion of that particular phase and the next phenological phase observations were started at their proper time. Thus, next phonological phase is not bound to appear after the completion of the first one.

During Rabi 2006-07, rainfall remained normal and optimum amount of moisture provided conducive environment during germination stage (Fig. 3a). Rainfall occurred during November and December was optimum and fulfill the water requirement at early stage. During February, 2007, rainfall was more than normal that was sufficient to meet the water requirement at shooting stage. Maximum temperature exceeded 20ºC in March reaching 30ºC in April conducive for maturity of the crop. Minimum temperature above 5ºC in February was also favorable for the crop growth. The mean NDVI values collected during different growth periods of the wheat crop ranged between 0.1 - 0.9. The mean NDVI value was maximum in the heading

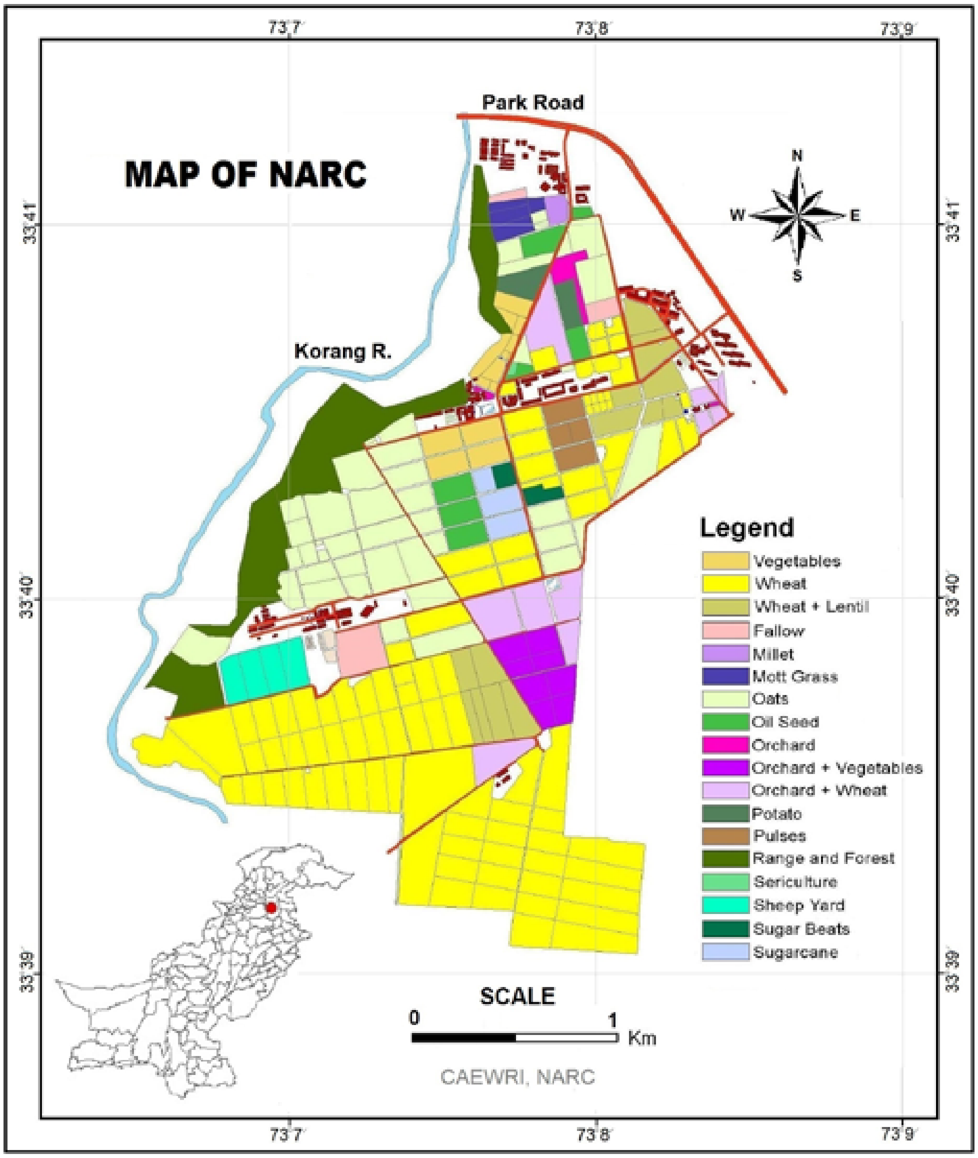

Fig. 1. Location of study area indicating layout of the cropping fields.

Fig. 2a. Handheld Green Seeker instrument for NDVI measurement.

Fig. 2b. A handheld NDVI sensor to assess crop health.

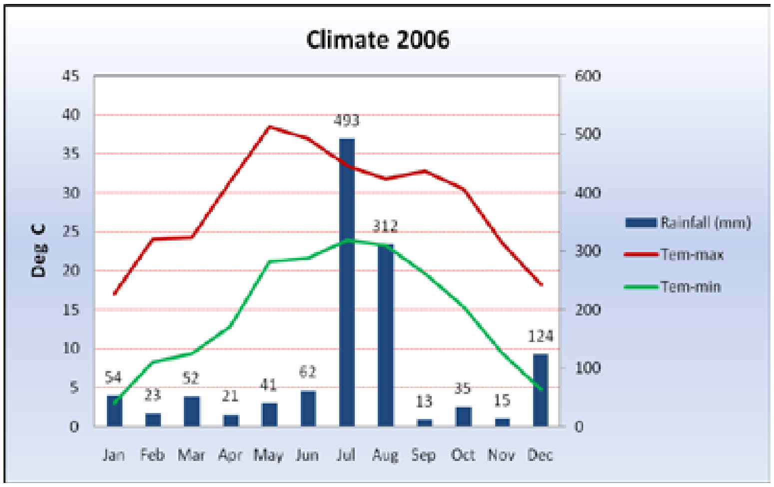

Fig. 3a. Monthly climate data of NARC weather station during 2006.

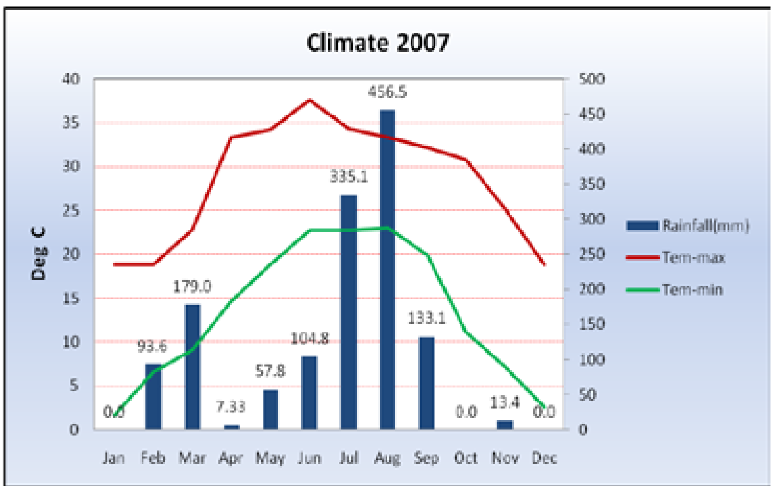

Fig. 3b. Monthly climate data of NARC during 2007.

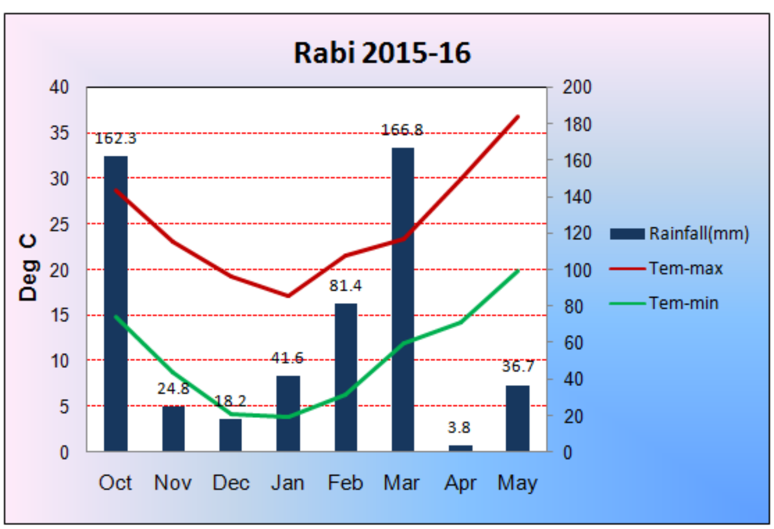

Fig. 3c. Monthly climate data of NARC during Rabi (2015-16).

stage, e.g., 0.88 on 23 February followed by maturity stage of the crop e.g. 0.84 on 30 March (Table 1 and Fig. 4). The least value i.e. 0.12 was on 29 November during the tillering followed by 0.22 on 30 April during the harvesting stage. However, the ratio Red/NIR was found maximum at tillering followed b harvesting stage of the crop. Color infrared gives a good indication of the amount or volume of biomass, therefore lower values of red reflectance reveal vegetation damage or loss. Different growth stages of the wheat crop are shown in Fig. 5.

The rice crop was transplanted on plot no. C4-A on 20-07-2007. During Kharif 2007, the rainfalls of July and August remained above 300mm in Fig. 3b. The maximum temperature of August to October was between 30-35ºC, favorable for rice crop maturity. The mean NDVI values collected through the GS instrument during different growth periods of rice crop ranged between 0.03 - 0.4. The mean NDVI value was maximum on the heading stage while it was minimum during the harvesting stage of the rice crop (Table 2 and Fig. 6). The Red/ NIR ratio was found maximum in the tillering followed by maturity stage of the crop. The crop was harvested on 5-11-2007. Different growth stages of rice crop are shown in Fig. 7.

In Rabi 2015-16, NDVI values were again collected of various stages of wheat besides oat crop using a pocket NDVI sensor. The rainfall during Rabi 2015-16 remained normal and optimum amount of moisture provided conducive environment during germination stage of the crops. Rainfall occurred during October was favorable to fulfill the water requirement at early stage of the crop (Fig. 3c). Similarly, February rainfall was also sufficient to meet

Fig. 4. NDVI curve of wheat crop during Rabi 2006-07.

Table 1. Field data of wheat crop collected during Rabi 2006-07.

S. No.	Date	NDVI	Red/NIR	Crop stage
1	29-11-2006	0.12	0.78	Tillering
2	03-01-2007	0.75		Tillering
3	02-02-2007	0.76	0.14	Shooting
4	23-02-2007	0.88	0.06	Heading
5	30-03-2007	0.84	0.08	Maturity
6	30-04-2007	0.22	0.63	Ripening

Table 2: Field data of rice crop collected during Kharif 2007

S. No.	Date	NDVI	Red/NIR	Crop stage
1.	26-07-2007	0.40	0.17	Tillering
2.	20-08-2007	0.32	0.04	Panicle initiation
3.	13-09-2007	0.61	0.12	Heading/flowering
4.	29-10-2007	0.03	0.06	Maturity

the water requirement at shooting stage. Minimum temperature was above 5ºC in February while maximum temperature exceeded 20ºC in February reaching near 30ºC in April. The mean NDVI values collected at different growth periods of wheat crop during Rabi 2015-16 ranged between 0.25 - 0.81 (Table 3 and Fig. 8). The NDVI value was high during heading stage of crop, i.e., 0.8 on 8 March. The least values were observed on ripening stage on 8 December tillering stage, i.e., 0.16 on 26 April and 0.25 at start of the tillering stage. The crop was harvested on 17 May, 2016. Various growth stages of the wheat crop are shown in Fig. 9. Overall, the NDVI data of wheat crop during the Rabi seasons of 2006-07 and 2015-16 exhibited peak values during the heading stage of the crop i.e. mainly in the month of March, indicating full vigor and healthy crop conditions. The variation in values are due to variable time of data taken, crop variety, fertilizer input and irrigation practice. The higher values of crop cover (i.e. exceeding 0.8) also points toward better crop health under favorable climatic conditions during the crop growth period. The relatively lower NDVI values of wheat during Rabi 2015-16 is likely due to rainfed condition in the field that resulted in nominal growth of the crop than the one grown in the irrigated field.

Fig. 5. Different growth stages of the wheat crop during Rabi 2006-07.

Table 3. NDVI data of wheat and oat crops collected during Rabi 2015-16.

S. No.	Date	Wheat	Oats
1	8-12-2015	0.25	0.60
2	9-02-2016	0.42	0.70
3	22-02-2016	0.65	0.76
4	8-03-2016	0.81	0.78
5	11-04-2016	0.60	0.56
6	26-04-2016	0.16	0.37

The oat crop (NARC 2011) was sown on plot no. C4-A on 12 November, 2015. The NDVI values of oat crop during Rabi 2015-16 ranged between 0.37 - 0.78 (Table 3). The NDVI value was maximum i.e. 0.78 on 8 March followed by 0.76 on 22 February (Table 3 and Fig. 8). The least value was on 26 April i.e. 0.37 (maturity stage). The crop was harvested on 11 May, 2016. Various growth stages of the crop are shown in Fig. 10. Overall, the values of wheat and oat crops indicate a similar pattern, but a slight

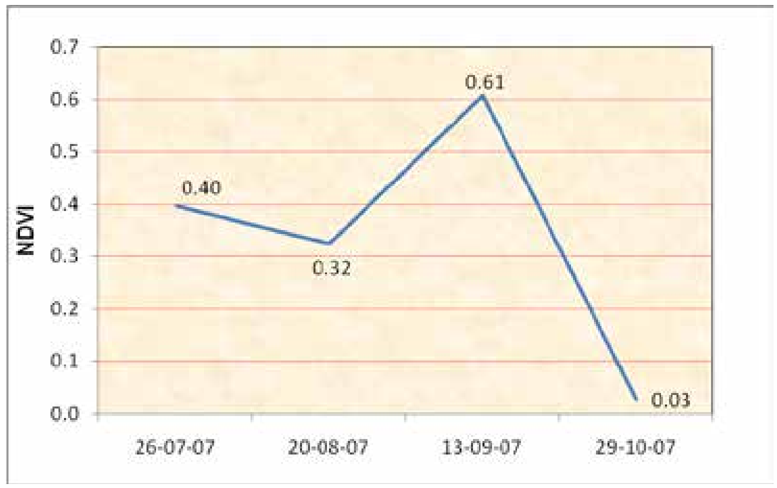

Fig. 6. NDVI curve of rice crop during Kharif 2007.

Fig. 7. Different growth stages of the rice crop during Kharif 2007.

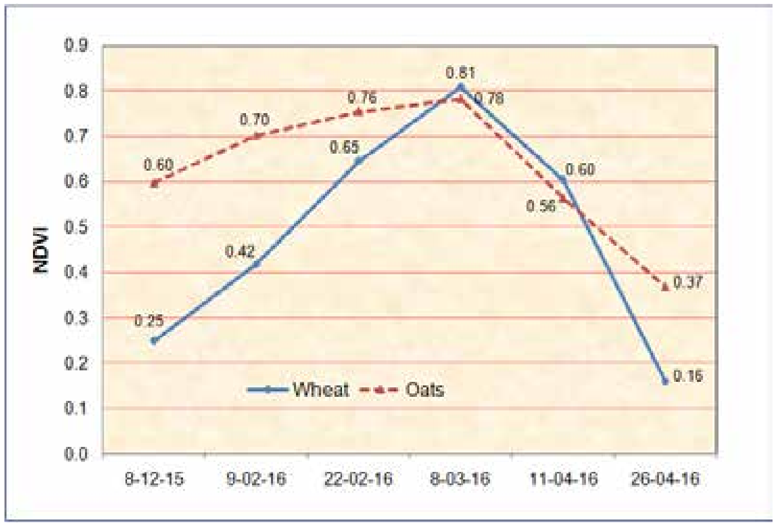

Fig. 8. NDVI curves of wheat and oat crops during Rabi 2015-16.

Fig. 9. Different growth stages of the wheat crop during Rabi 2015-16.

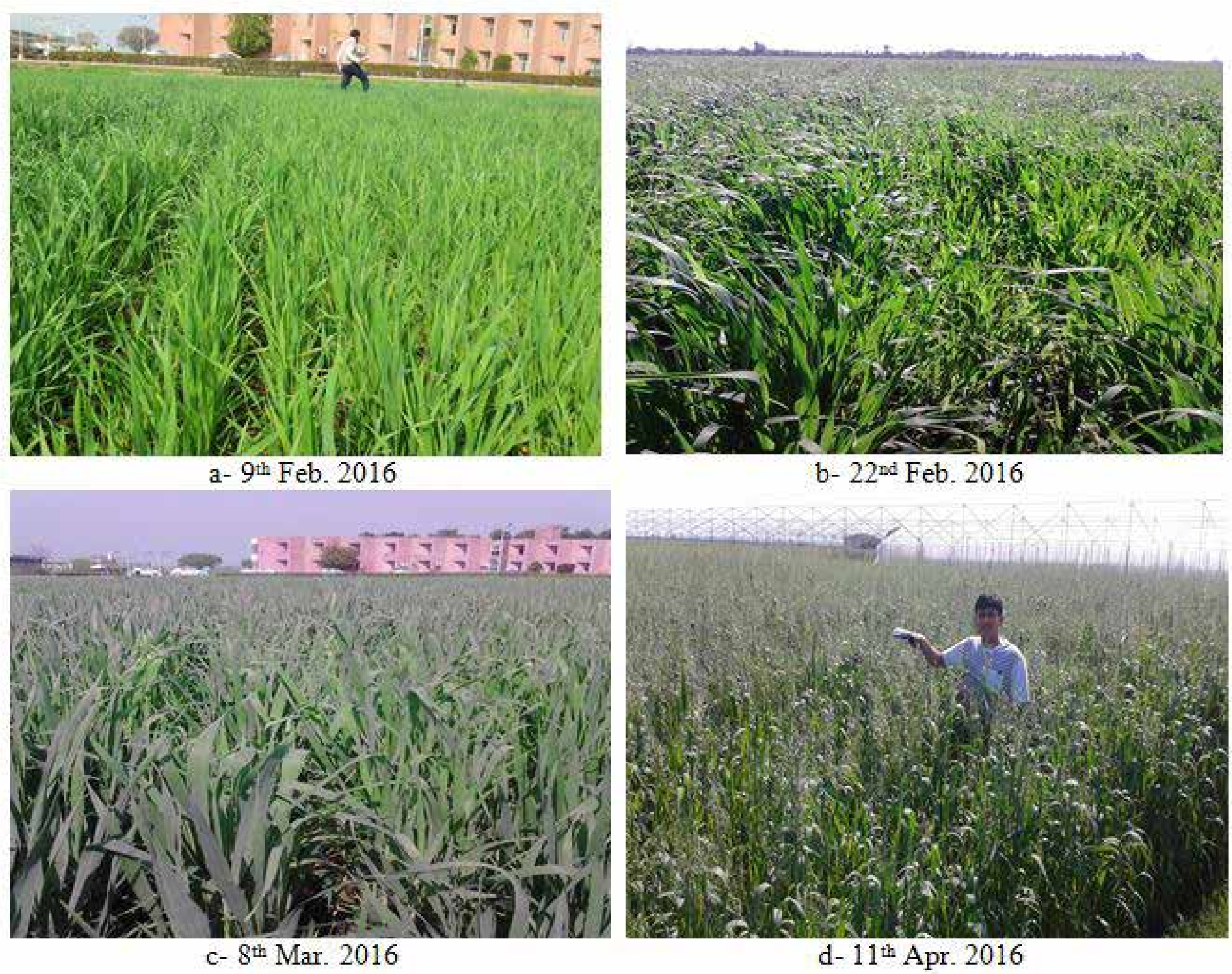

Fig. 10. Different growth stages of the oat crop during Rabi 2015-16.

difference is visible before the heading and near the harvesting stages of the crops. According to Teal et al. [19], the NDVI values are highly correlated with total above ground biomass and crop growth stage is a major factor in predicting yield potential [20]. The NDVI curves of various crops in this study exhibit more or less optimum growth of the crops due to factors like favorable climatic conditions as observed during their growing periods. Raun et al. [20] established a nondestructive estimation of crop yield potential using spectral measurements of wheat crop. This study could provide base for predicting crops yield potential through establishing a relationship between NDVI and grain yield under variable agro-environments.

4. CONCLUSIONS

The spectral data of the wheat crop indicated NDVI values ranging between 0.12 - 0.88 while the values for various growth stages of the rice crop ranged between 0.03 - 0.61 at NARC field station during surveyed periods. The value was maximum in the heading stage likely due to high greenness and plant vigor. Variations in NDVI values were observed in the rainfed fields due to heterogeneous crop cover resulting from variable moisture conditions, fertilizer use, soil type and sowing practices. A spectral repository of various crops and the surrounding land covers needs to be developed for different agro-ecological regions of the country so as to provide base for satellite based crop yield forecasting in future. As crop varieties and climatic pattern are changing regularly with time so it should become a part of long term monitoring programme in the country.

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