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Gossypium Plant Health Detection from Hyperspectral Data using Various Disease Indices

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Abstract*: Cotton is the world's most prevalent beneficial non-food crop, producing revenue for over 250 million people globally and employing nearly 7% of all workers in developing nations. About half of all fabrics are produced with cotton. In such a case if the cotton plant gets affected due to disease can lead to economic and personal loss. These diseases may be one of the reasons that could significantly reduce the supply of cotton to the market, which result in a low agricultural economy. Faster and more accurate prediction of leaf diseases in crops could help to develop an early treatment technique while significantly reducing economic losses. The traditional monitoring system is time-consuming and expensive. In this paper, we have discussed hyperspectral sensor ASD FieldSpec4 which are less time consuming and non-destructive. Spectral Vegetation Indices (SVI) is strongly linked to the chemical composition of the plant leaf such as chlorophyll, nitrogen, carotenoid, and anthocyanin. The linear regression models were developed for the calculation of correlations between spectral indices and plant composition using MATLAB 2018.

***Keywords*: *ASD FieldSpec4, Linear regression, Plant disease, Vegetation Indices*.**

I. INTRODUCTION

Plant diseases are responsible for significant economic failures in the global agriculture industry. Precise assessment of severity and adverse impacts of plant disease affects the quality and quantity of the crop. In precision agriculture, it is important to detect and monitor crop diseases as it reduces the spreading of the diseases and makes the management practices easy [1]. Automatic crop planning strategies and disease prevention strategies to stop spreading of the crop diseases are needed. Standard monitoring techniques are often based on plant agronomists inspecting the plant regularly for recognizable indication signs. A big team of experts and their continuous monitoring is needed for doing so, which results in a high cost in terms of both time and labor. When environmental conditions are favorable, an outbreak of these diseases can spread rapidly, resulting in significant loss of yield and quality. Each disease has its characteristics and, consequently, requires corresponding measures. Therefore, developing technologies for precise monitoring and identifying the occurrence of diseases is extremely important in agricultural management.

However, today's technology is growing rapidly in which there are optical detectors accessible that operate non-invasively. These sensors can assist the detection and identification of plant disease in multiple areas of implementation. This trend is particularly beneficial for precision farming and plant phenotyping. The optical imaging detectors provide accurate data depending on various electromagnetic spectra and therefore allow plant disease prediction [2]. Optical-based methods have become more primary in the non-destructive testing and monitoring of agricultural goods. Hyperspectral technology is one of the commonly used implicit methods for the identification of plant diseases [3].

Earlier hyperspectral imaging system were available, researchers measured special effects grounded on color data they have used multispectral imaging data, or hyperspectral data, point-source system (like spectroradiometers which cannot produce a spatial image) to obtain color data. Once obtained, to provide helpful data, the subsequent big numerical datasets must be analyzed. In such huge data sets, a realistic and convenient approach is to assume only a small amount of points in the wavelength band, searching modifications at predetermined crucial locations in the spectrum. This includes combining two or more wavelengths, frequently referred to as ' index'.

One of the most common and important index is the normalized difference vegetation index (NDVI) used to measure plant health status [4, 5]. For instance, NDVI was used to identify stress induced by Sunn insect / cereal plague in wheat [6]. Most of the indexes are very appropriate and perform only well with datasets they have been created for [7]. There are disease-centric study based on the development of disease index to identify and evaluate particular diseases, for example, one research used the leaf rust disease severity index (LRDSI) with an precision of 87–91 percent in the detection of leaf rust (Puccinia triticina) on wheat crop [8].

Another commonly used technique is to identify modifications in the red / near infrared edge sudden rise in reflection. This ' red edge' point is a minor part of the electromagnetic spectrum (690–740 nm) where the range ends and the near-infrared begins as shown in Figure 3. This portion has a major change in spectral response to green crop content, since chlorophyll heavily absorbs wavelengths up to about 700 nm, and therefore the content has low reflection in this spectrum, but it highly reflects the infrared region (from about 720 nm). Cho et.al. [9] defines various algorithms which obtain or identify the red edge.

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A red edge-based crop disease index (Blumeria graminis f. sp. Tritici) was used to identify powdery mildew in wheat, but it wasn't as precise as the Partial Least Squares Regression (PLSR), a method using a statistical approach [10].Nitrogen is an essential component for proper growth of the plant. Ben Zhao et.al. developed new spectral indices for summer maize. The best sensitive spectral bands were used as 710 nm and 512 nm to estimate Nitrogen nutrition index (NNI) values of summer maize [11].

II. METHODS AND MATERIAL

A. Study Area

The geographical location of the study area was $19^0$55'51.70255" N latitude and $75^0$21'513.47851" E longitude of Jalgaon road Hwy Harsul Aurangabad (MS) Maharashtra, India on 11 September 2019. The 40 sample for healthy and diseased (Leaf blight) Gossypium (Cotton) were collected.

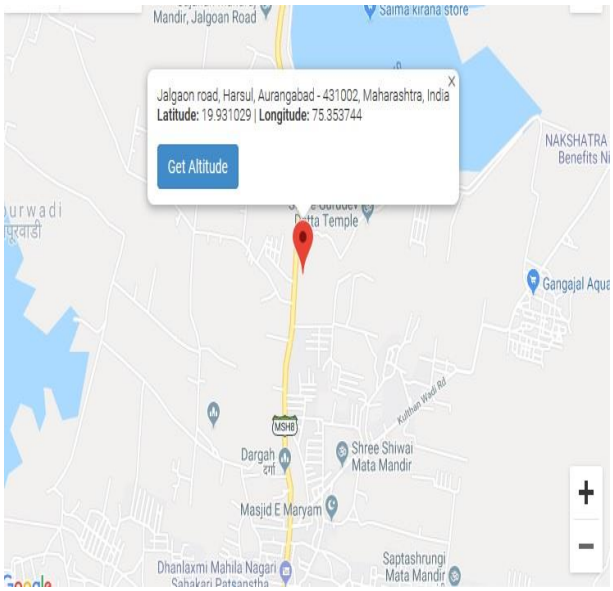

Fig.1. Location for study area

B. Hyperspectral Non-Imaging sensor

The ASD FieldSpec4 Hi-Res spectroradiometer's 3 nm VNIR, 8 nm SWIR spectral accuracy delivers excellent spectral results across the complete spectrum of solar irradiance (350–2500 nm). The improved spatial accuracy in the SWIR spectrum (1000–2500 nm) is especially helpful in the detection and identification of compounds with narrow spectral characteristics in longer range such as modification mineralogy and atmospheric gas assessment. Before recording, white reflectance panel was used for device calibration and optimization. Lens of Field of View (FOV) 8 degree was used with height of 5 cm. Perfect black surface is used at the time of sample collection. Total 40 leaves were used for healthy and diseased 20 samples each. RS3 software was used for the visualization of the raw spectra and pre-processing of cotton leaf.

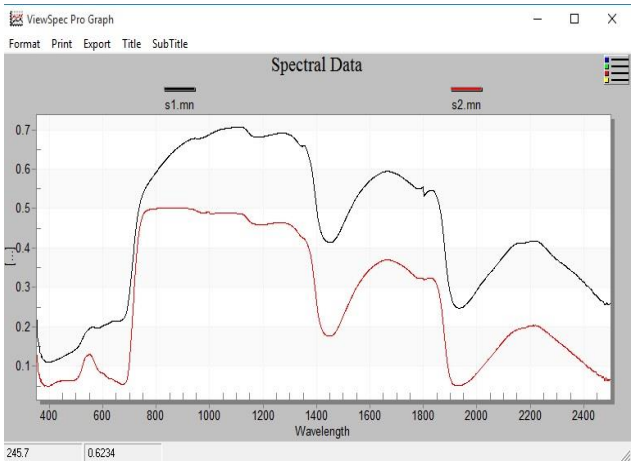

Fig.2. s1 is healthy spectra and s2 is diseased spectra

C. Spectral Vegetation Indices (SVI)

Spectral vegetation indices (SVI) is used in the hyperspectral data for plant disease and healthy discrimination, as SVI are closely related to particular plant component like chlorophyll a, chlorophyll b, carotenoid, nitrogen, xanthophyll and anthocyanin. A benefit of SVIs is that data dimensionality of hyper spectral data is reduced [12, 13].

III. RESULT AND DISCUSSION

A. Pigment Results

The Pigment Specific Normalized Difference (PSND) equations are as follows:

$$\text{PSND-a} = (R_{800} - R_{675})/(R_{800} + R_{675}) \quad (1)$$

$$\text{PSND-b} = (R_{800} - R_{650})/(R_{800} + R_{500}) \quad (2)$$

$$\text{PSND-c} = (R_{800} - R_{500})/(R_{800} + R_{500}) \quad (3)$$

$$\text{PSND-d} = (R_{805} - R_{670})/(R_{805} + R_{670}) \quad (4)$$

The above equations were applied on the healthy and diseased samples. It was observed that the PSND-a with R^2 value 0.351, PSND-b with R^2 value 0.304 and PSND-d with R^2 values 0.353 is high in healthy crop as compared to diseased crop. Carotenoid values were high in healthy as compared to the disease plant with R^2 value 0.209. Following Fig.2. shows the spectral signature for healthy and disease cotton.

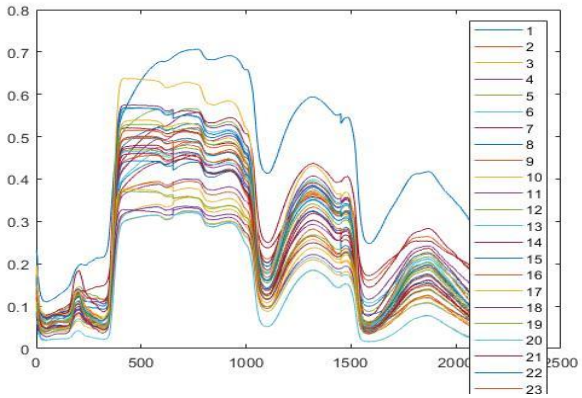

Fig.3. Spectral Signature for Cotton healthy and disease crop

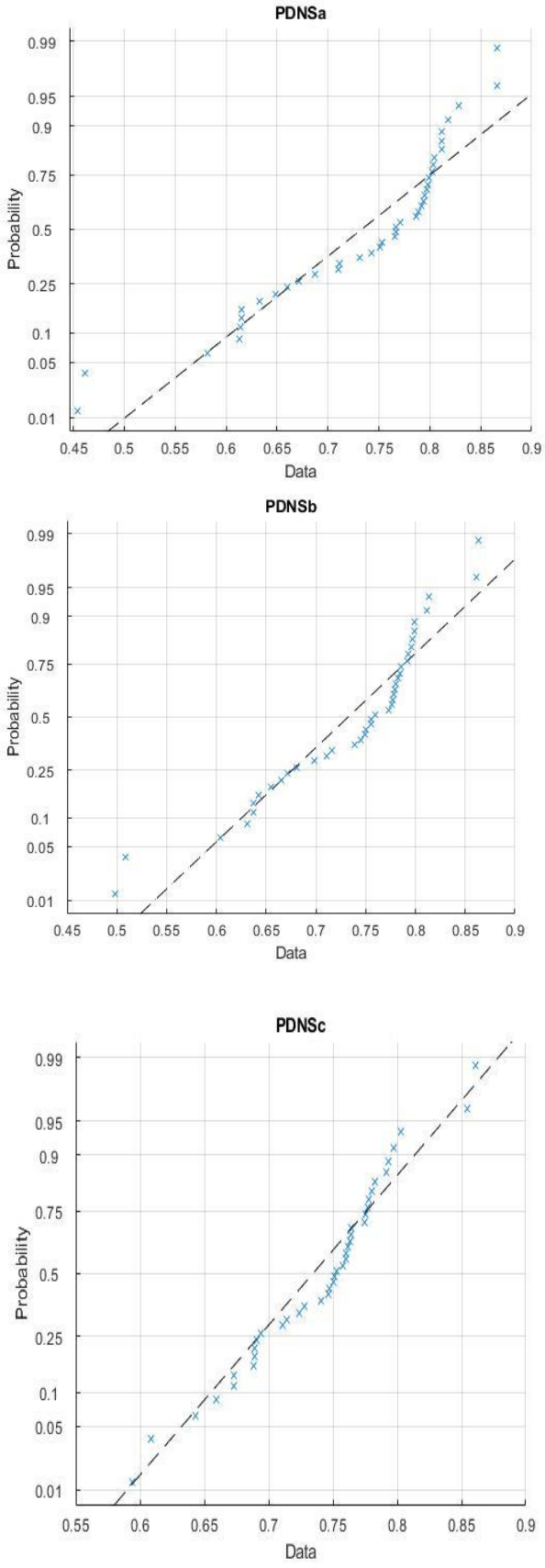

Fig.4. linear regression for PDNS-a, PDNS-b, PDNS-c

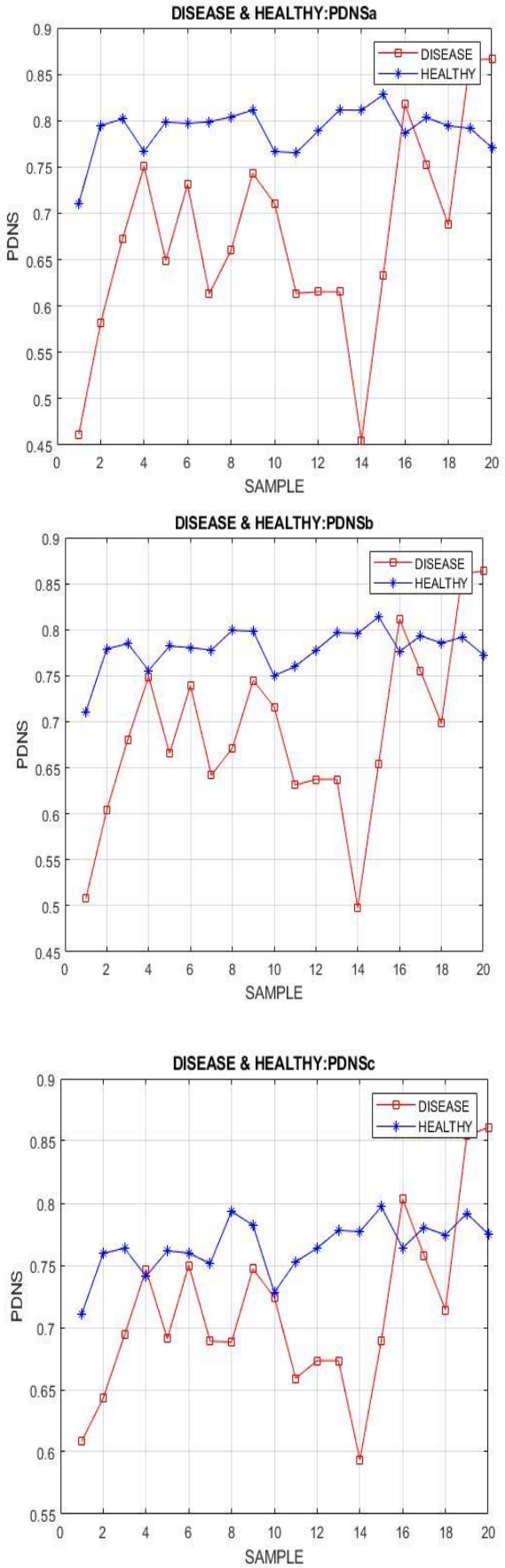

Fig.5. Graphical Representation of PSND-a, PSND-b, PSND-c

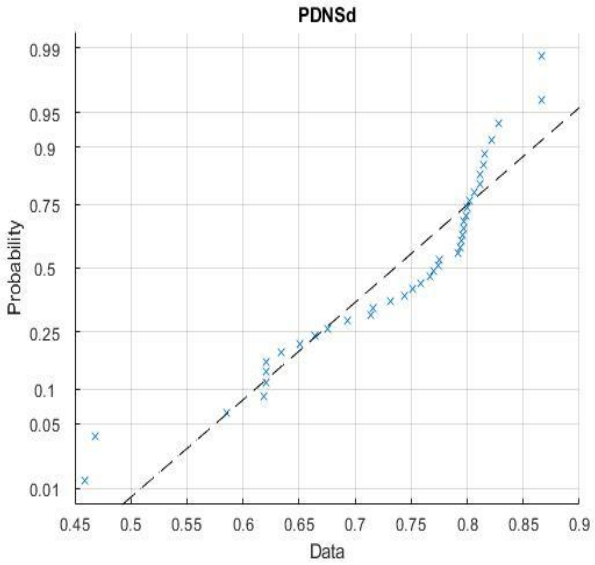

Fig.6.Linear Regression for PSND-d

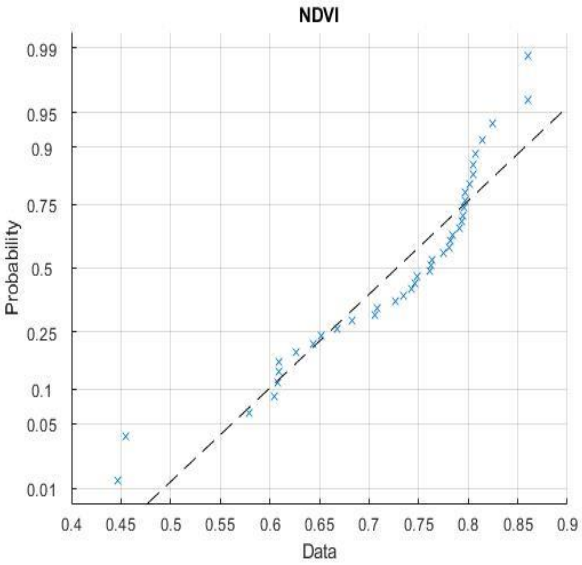

Fig.8.Linear Regression for NDVI

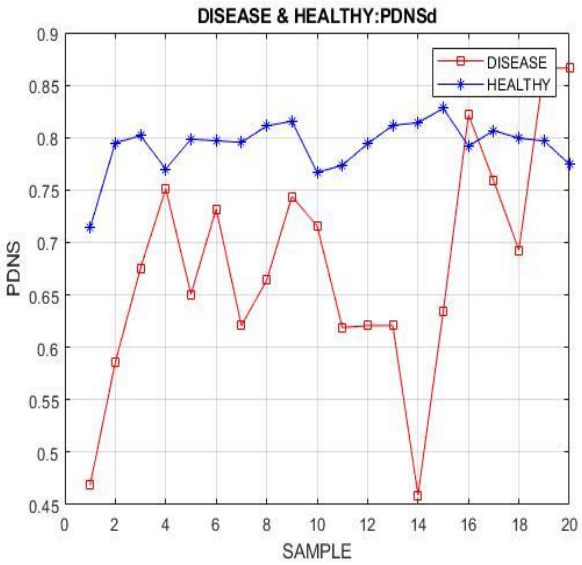

Fig.7. Graphical Representation of PSND-d

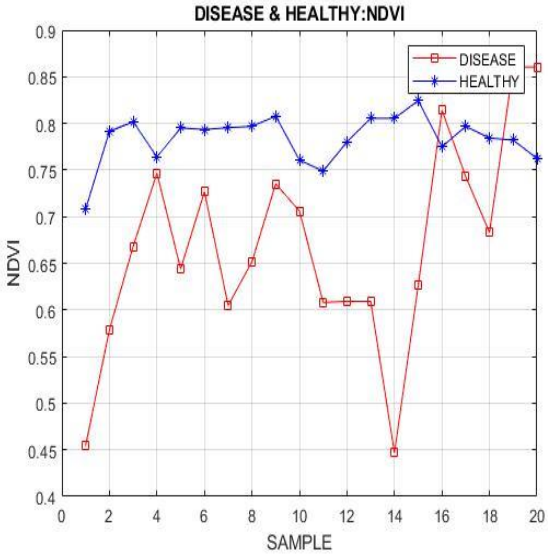

Fig.9. Graphical Representation of NDVI

B. Normalized Difference Vegetation Index (NDVI)

We have also calculated the Normalized Difference Vegetation Index (NDVI) using wavelength 800nm and 680nm for NIR and RED band respectively. Following formula is used for calculating NDVI.

$$NDVI = (R_{800} - R_{680}) / (R_{800} + R_{680}) \quad (4)$$

The above formula generates the values between -1 to 1. It is been observed that values for healthy crop is higher than the diseased crop. The R^2 value for NDVI was 0.348.

C. Nitrogen reflectance index (NRI)

Nitrogen (N) is important factor for the proper growth of the plant. Nitrogen deficiency leads to improper growth in plant and diseases. We have calculated the Nitrogen reflectance index and observed that the nitrogen is high in healthy crop than the diseased crop. Following formula was used in calculation of the NRI. The R^2 value for NRI was 0.662.

$$NRI = (R_{700} - R_{670}) / (R_{570} + R_{670}) \quad (5)$$

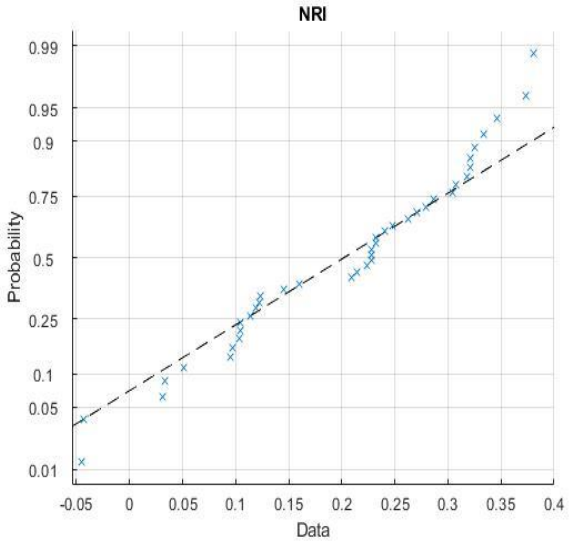

Fig.10.Linear Regression for NRI

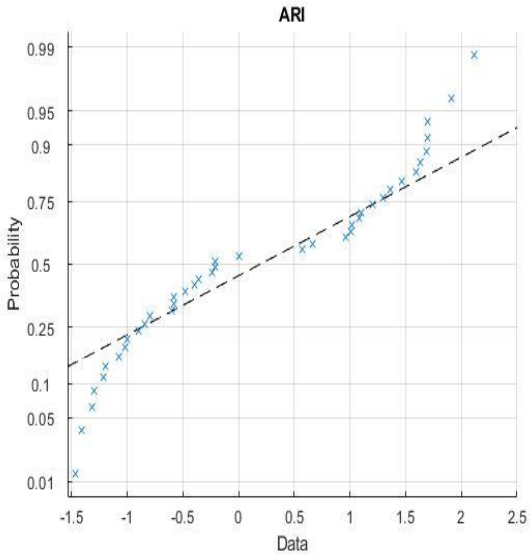

Fig.12. linear regression for ARI

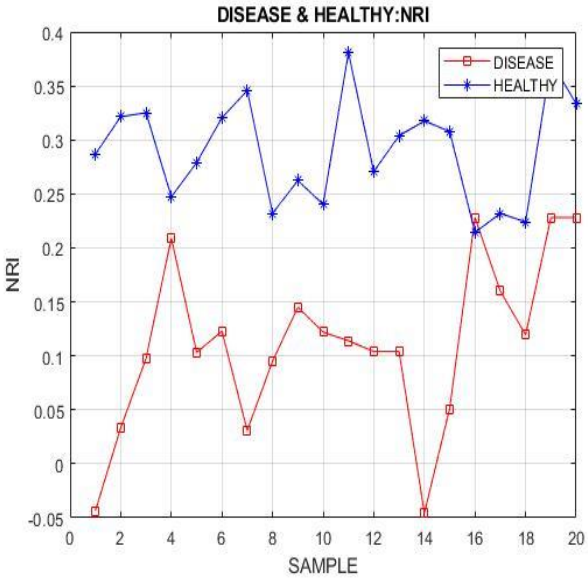

Fig.11.Graphical Representation of NRI

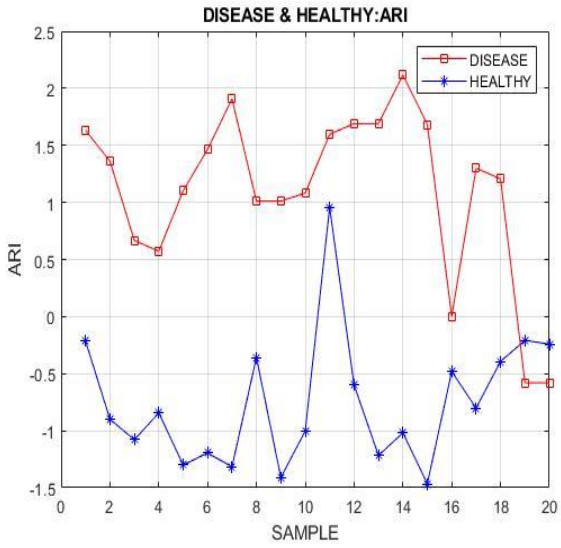

Fig.13.Graphical Representation of ARI

D. Anthocyanin reflectance index (ARI)

It was observed that if Anthocyanin Reflectance Index is high in cotton crop which cause leaf bight disease on the crop. Following band was used to calculate the ARI. The R^2 value for ARI was 0.665.

$$ARI = (1/R_{550}) - (1/R_{700}) \quad (6)$$

Table- I. PSND-a, PSND-b, carotenoid (c), PSND-d Disease Indices values

Sr .no	PSND							
	Disease				*Healthy*			
	a	***b***	***c***	***d***	***a***	***b***	***c***	***d***
1	0.4617	0.5082	0.6087	0.4686	0.7110	0.7110	0.7110	0.7138
2	0.5814	0.6041	0.6431	0.5857	0.7946	0.7792	0.7597	0.7950
3	0.6718	0.6807	0.6940	0.6754	0.8018	0.7848	0.7637	0.8018
4	0.7506	0.7488	0.7465	0.7512	0.7668	0.7557	0.7411	0.7701
5	0.6491	0.6656	0.6911	0.6507	0.7985	0.7821	0.7616	0.7985
6	0.7312	0.7391	0.7500	0.7319	0.7969	0.7805	0.7598	0.7969

7	0.6131	0.6420	0.6890	0.6207	0.7988	0.7778	0.7514	0.7954
8	0.6599	0.6712	0.6884	0.6639	0.8039	0.7992	0.7934	0.8110
9	0.7431	0.7448	0.7471	0.7437	0.8115	0.7984	0.7823	0.8156
10	0.7105	0.7162	0.7241	0.7158	0.7667	0.7500	0.7282	0.7667
11	0.6138	0.6311	0.6592	0.6189	0.7653	0.7599	0.7529	0.7736
12	0.6154	0.6375	0.6733	0.6207	0.7885	0.7776	0.7638	0.7941
13	0.6154	0.6375	0.6733	0.6207	0.8116	0.7966	0.7782	0.8116
14	0.4545	0.4980	0.5936	0.4592	0.8112	0.7959	0.7771	0.8141
15	0.6324	0.6544	0.6892	0.6339	0.8279	0.8139	0.7970	0.8279
16	0.8178	0.8112	0.8032	0.8219	0.7862	0.7764	0.7640	0.7918
17	0.7529	0.7550	0.7579	0.7586	0.8033	0.7932	0.7806	0.8066
18	0.6875	0.6984	0.7143	0.6927	0.7944	0.7855	0.7744	0.7994
19	0.8659	0.8606	0.8545	0.8663	0.7918	0.7918	0.7918	0.7967
20	0.8663	0.8636	0.8606	0.8663	0.7709	0.7727	0.7751	0.7746

Table- II. NDVI, NRI, ARI, PRI Disease Indices Values

Sr. no	PRI		NDVI		NRI		ARI	
	Healthy	*Disease*	*Disease*	*Healthy*	*Disease*	*Healthy*	*Disease*	*Healthy*
1	0.440217391	0.625641026	0.454545	0.708197	-0.04348	0.286885	1.631702	-0.21493
2	0.484848485	0.6796875	0.578571	0.791367	0.033333	0.321429	1.360887	-0.89882
3	0.484615385	0.636363636	0.668122	0.801802	0.097561	0.325153	0.667048	-1.07962
4	0.551470588	0.516483516	0.746479	0.763934	0.208955	0.247312	0.572344	-0.84378
5	0.540540541	0.554794521	0.643963	0.795066	0.103175	0.278912	1.102189	-1.30027
6	0.491935484	0.585714286	0.726542	0.793499	0.122807	0.320513	1.465201	-1.19474
7	0.461538462	0.639344262	0.604811	0.795367	0.030837	0.345679	1.907413	-1.3167
8	0.559139785	0.633587786	0.651591	0.796875	0.095023	0.232	1.011071	-0.35842
9	0.553191489	0.588235294	0.73516	0.807771	0.145038	0.262295	1.012018	-1.40989
10	0.592307692	0.636363636	0.706037	0.760684	0.121951	0.240223	1.082251	-1.00334
11	0.376	0.579710145	0.607985	0.748837	0.113924	0.380645	1.596659	0.957746
12	0.567375887	0.573643411	0.609195	0.780186	0.104072	0.270718	1.691332	-0.60011
13	0.511811024	0.573643411	0.609195	0.805461	0.104072	0.303797	1.691332	-1.21689
14	0.52173913	0.651851852	0.446655	0.805423	-0.04561	0.317647	2.116402	-1.01809
15	0.523809524	0.62962963	0.625984	0.824427	0.05102	0.307692	1.683502	-1.4652
16	0.629032258	0.56097561	0.814141	0.775	0.22807	0.214286	0	-0.48249
17	0.605769231	0.6	0.742857	0.796733	0.16	0.231884	1.300108	-0.80128
18	0.605839416	0.597560976	0.683117	0.784314	0.119403	0.224044	1.206111	-0.39304
19	0.343434343	0.523809524	0.860182	0.782016	0.22807	0.372881	-0.58072	-0.20827
20	0.380530973	0.523809524	0.860606	0.76247	0.22807	0.333333	-0.58072	-0.24135

Table -III: Stastical values for SVI

SVI	R^2	RMSE	Adjusted R^2	p-value
PSND-a	0.351	0.413	0.334	5.71e-05
PSND-b	0.304	0.428	0.286	0.00022
PSND-c	0.209	0.456	0.189	0.00299
ARI	0.665	0.297	0.656	1.45e-10
NRI	0.662	0.298	0.653	1.76e-10
NDVI	0.348	0.414	0.33	6.26e-05

IV. CONCLUSION

Hyperspectral technology is non-distractive and less time consuming as compared to the traditional technology. We have collected dataset for cotton healthy and diseased leaf using ASD FieldSpec4 20 samples each. Various plant parameters like PSND-a, PSND-b, carotenoid, anthocyanin, nitrogen were calculated using vegetation indices. Statistical analysis like R^2, RMSE, p-values, and

Adjusted R^2 values were calculated using the MATLAB 2018. According to the graphical observation nitrogen, pigment, carotenoid is high in healthy plant, while anthocyanin is high in diseased plant.

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