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Application of spectroradiometer SVC HR-1024i infrastructure in the study of downy mildew of bitter gourd caused by *Pseudoperonospora cubensis* (Berkeley & Curtis) Rostovtsev

Asalkar UA, Gorantiwar SD and Bhalekar MN

Abstract
Within the genus *Pseudoperonospora* (Peronosporaceae), the most popular and economically important species are *Pseudoperonospora cubensis*, Rostovzev, which causes downy mildew disease in bitter gourd. Seven types fungicidal treatments were applied during this research trial on bitter gourd such as 1) Absolute control (water spray), 2) Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit, 3) GI Chitosan @ 1 ml/lit, 4) Potassium salt of active phosphorus @ 4 g/lit, 5) T_2 and T_3 alternatively, 6) T_2 and T_4 alternatively and 7) T_2, T_3, and T_4 alternatively. Spectroradiometer was placed in Hyspec laboratory CAAST-CSAWM MPKV Rahuri. Treatment wise healthy and downy mildew diseased leaf samples were collected and brought into the Hyspec laboratory for further investigation. Spectroradiometer has given the spectral signature of each treatment having wavelength 350nm to 2500nm. The data obtained by this technique was analyzed in the software SVC HR-1024i which indicates the NDVI (normal difference vegetation index) values. Overall present research showed the highest NDVI mean values were obtained in treatment 7) T_2, T_3, and T_4 alternatively i.e (Metalaxyl 4% + Mancozeb 64% WP, GI Chitosan @ 1 ml/lit and Potassium salt of active phosphorus @ 4 g/lit alternatively) followed by T_4 (Potassium salt of active phosphorus @ 4 g/lit), T_6 (T_2 and T_4 alternatively, T_5 (T_2 and T_3 alternatively), T_2 (Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit), T_3 (GI Chitosan @ 1 ml/lit. The minimum NDVI mean was noticed under treatment T_1 (absolute control: water spray). All attempted disease management treatments (T_2 to T_6) were significantly superior over T_1 (absolute control: water spray).

Keywords: *Pseudoperonospora cubensis*, spectroradiometer SVC HR-1024i, bitter gourd and downy mildew

1. Introduction
During this study hyperspectral imaging sensor (spectroradiometer SVC HR-1024i) was used to capture and process a picture with a large number of wavelengths in the form of an electromagnetic spectrum. The electromagnetic spectrum is a collection of images captured at various wavelengths. spectroradiometer SVC HR-1024i estimate different vegetation indices (NDVI- normal difference vegetation index). The NDVI is computed as the difference between near-infrared (NIR) and red (RED) reflectance divided by their sum. (Agenagnew, Gessesse and Melesse, 2019) [3]. The value of NDVI varied between – 1.0 to + 1.0 and NDVI is an index to measure healthy green vegetation. Bitter gourd belongs to the Cucurbitaceae family and is planted in several parts of Maharashtra and India. The field research trial was conducted during the year, 2022 on the research farm of All India coordinated research project (AICRP) Vegetables, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. Hyperspectral imaging is a cutting-edge spectroscopy-based remote sensing technique with specialized sensors which detected the light reflected by the bitter gourd crop infected by *pseudoperonospora cubensis* pathogen which causes downy mildew disease. Spectroradiometer is the infrastructure used for research trial during year 2022 which was available at HySpecLab. Centre for Advance Agriculture Science and Technology on Climate-Smart Agriculture and Water Management (CAAST- CSAWM). Indian Council of Agriculture Research (ICAR) Government of India, New Delhi at Mahatma Phule Krishi Vidyapeeth, Rahuri.

2. Materials and Methods

2.1 G I Chitosan

The GI chitosan (Low Molecular Weight Chitosan) was kindly provided by Vasantdada Sugar Institute, Pune.

2.2 Potassium Salt of Active Phosphorus (PSAP)

PSAP - Potassium Salt of Active Phosphorus was procured from Isha Agro, Pune.

2.3 Ridomil Gold

Metalaxyl 4% + Mancozeb 64% WP was obtained from the local market Rahuri.

2.4 Advanced hyperspectral technique

Spectroradiometer (SVCHR-1024i) was used to analyze the normal difference vegetation index (NDVI) index data. This advanced facility was made available by (HySpecLab) Centre for Advance Agriculture Science and Technology on Climate-Smart Agriculture and Water Management (CAAST-CSAWM). Indian Council of Agriculture Research (ICAR) Government of India, New Delhi at Mahatma Phule Krishi Vidyapeeth, Rahuri.

The NDVI is computed as the difference between near-infrared (NIR) and red (RED) reflectance divided by their sum. (Agenagnew, Gessesse and Melesse, 2019) [3].

Infrastructure	Specification	Wavelength	Software used
Spectroradiometer	Model: SVCHR-1024i	350 nm to 2500 nm covering UV, Visible, IR, NIR, and SWIR wavelengths.	SVC HR – 1024i

2.5 Experiment site

The experiment was conducted on the experimental farm of the All India Coordinated Research Project on Bitter gourd Vegetable, MPKV, Rahuri. during year 2022.

2.6 Layout and plan

The field experiments were conducted in Randomized Block Design with three replication and seven treatments for disease management studies.

2.7 Treatment details

1. Absolute control (water spray)
2. Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit
3. GI Chitosan @ 1 ml/lit
4. Potassium salt of active phosphorus @ 4 g/lit
5. T_2 and T_3 alternatively
6. T_2 and T_4 alternatively
7. T_2, T_3, and T_4 alternativel

3. Results and discussion

During this study, hyperspectral imaging technology (spectroradiometer SVC HR-1024i) was mainly used for normal difference vegetation index (NDVI) mapping, plant health analysis and early infection of downy mildew disease in bitter gourd during year 2022. hyperspectral imaging technology used to diagnose downy mildew disease faster and allow one to take preventive measures to lessen the damage caused by a pathogen.

3.1 NDVI after the first spray using spectroradiometer

Table 1 indicates the NDVI obtained after the first spray using spectroradiometer. In replication first (R_1) the treatment T_7 (T_2, T_3, and T_4 alternatively) showed the highest NDVI as 0.76. This was followed by T_4 (Potassium salt of active phosphorus @ 4 g/lit) and T_6 (T_2 and T_4 alternatively) as 0.71; T_5 (T_2 and T_3 alternatively) as 0.70, T_2 (Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit) as 0.69, T_3 (GI Chitosan @ 1 ml/lit) as 0.68. The lowest NDVI obtained in treatment T_1 absolute control (water spray) as 0.62. All attempted disease management treatments (T_2 to T_6) were significantly superior over T_1 (absolute control: water spray).

Similar trend of values was noticed among the treatments under replications II and III.

Table 1.1 revealed the NDVI mean values obtained after first spray using spectroradiometer. The highest NDVI mean was obtained in treatment T_7 (T_2, T_3, and T_4 alternatively) as 0.76. This treatment was statistically superior over rest of all the treatments. This was followed by T_4 (Potassium salt of active phosphorus @ 4 g/lit) as 0.73, T_6 (T_2 and T_4 alternatively) as 0.72, T_5 (T_2 and T_3 alternatively) as 0.71, T_2 (Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit) as 0.70, T_3 (GI Chitosan @ 1 ml/lit as 0.69. The minimum NDVI mean was noticed under treatment T_1 (absolute control: water spray) as 0.64. All attempted disease management treatments (T_2 to T_6) were significantly superior over T_1 (absolute control: water spray).

Table 1: Replication wise NDVI after first spray using spectroradiometer

Treatment details		RED	NIR	NDVI
Replication I (R_1)				
T_1	Absolute control (water spray)	8.58	37.55	0.62
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	6.91	37.72	0.69
T_3	GI Chitosan @ 1 ml/lit	7.09	38.61	0.68
T_4	Potassium salt of active phosphorus @ 4 g/lit	6.51	39.70	0.71
T_5	T_2 and T_3 alternatively	6.34	36.49	0.70
T_6	T_2 and T_4 alternatively	6.10	36.51	0.71
T_7	T_2, T_3 and T_4 alternatively	4.85	36.94	0.76
Replication II (R_2)				
T_1	Absolute control (water spray)	5.61	28.72	0.67
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	6.31	37.03	0.70
T_3	GI Chitosan @ 1 ml/lit	6.38	35.24	0.69
T_4	Potassium salt of active phosphorus @ 4 g/lit	5.70	38.54	0.74
T_5	T_2 and T_3 alternatively	6.51	38.68	0.71
T_6	T_2 and T_4 alternatively	6.09	39.12	0.73
T_7	T_2, T_3 and T_4 alternatively	5.50	41.25	0.76
Replication III (R_3)				
T_1	Absolute control (water spray)	9.50	39.63	0.61

T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	5.71	33.76	0.71
T_3	GI Chitosan @ 1 ml/lit	6.72	36.99	0.69
T_4	Potassium salt of active phosphorus @ 4 g/lit	5.97	38.80	0.73
T_5	T_2 and T_3 alternatively	6.10	38.20	0.72
T_6	T_2 and T_4 alternatively	5.90	37.37	0.72
T_7	T_2, T_3 and T_4 alternatively	5.11	40.67	0.77
RED = Red light, NIR= Near-infrared and NDVI= Normal difference vegetation index				

Table 1.1: NDVI mean after first spray using spectroradiometer

Tr. No.	Treatment details	NDVI mean
T_1	Absolute control (water spray)	0.64 (4.57)*
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	0.70 (4.80)
T_3	GI Chitosan @ 1 ml/lit	0.69 (4.76)
T_4	Potassium salt of active phosphorus @ 4 g/lit	0.73 (4.90)
T_5	T_2 and T_3 alternatively	0.71 (4.84)
T_6	T_2 and T_4 alternatively	0.72 (4.87)
T_7	T_2, T_3 and T_4 alternatively	0.76 (5.02)
S. E. (m) ±		0.008
C.D. at 5%		0.024
NDVI= Normal Difference Vegetation Index, * Values in parentheses are arc sin transformed		

3.2 NDVI after the second spray using spectroradiometer

Table 2 indicates the NDVI obtained after the second spray using spectroradiometer. In replication first (R_1) the treatment T_7 (T_2, T_3, and T_4 alternatively) showed the highest NDVI as 0.77. This was followed by T_4 (Potassium salt of active phosphorus @ 4 g/lit) as 0.73, T_6 (T_2 and T_4 alternatively) as 0.72, T_5 (T_2 and T_3 alternatively) as 0.69, T_2 (Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit) as 0.68, T_3 (GI Chitosan @ 1 ml/lit)as 0.66. The lowest NDVI obtained in treatment T_1 absolute control (water spray) as 0.64. All attempted disease management treatments (T_2 to T_6) were significantly superior over T_1 (absolute control: water spray).

Similar trend of values was noticed among the treatments under replications II and III.

Table 2.1 revealed the NDVI mean values obtained after second spray using spectroradiometer. The highest NDVI mean was obtained in treatment T_7 (T_2, T_3, and T_4 alternatively) as 0.74. This treatment was statistically superior over rest of all the treatments. This was followed by T_4 (Potassium salt of active phosphorus @ 4 g/lit) as 0.72, T_6 (T_2 and T_4 alternatively as 0.71, T_5 (T_2 and T_3 alternatively) as 0.68, T_2 (Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit) as 0.67, T_3 (GI Chitosan @ 1 ml/lit as 0.64. The minimum NDVI mean was noticed under treatment T_1 (absolute control: water spray) as 0.60. All attempted disease management treatments (T_2 to T_6) were significantly superior over T_1 (absolute control: water spray).

Table 2: Replication wise NDVI after second spray using spectroradiometer

Treatment details		RED	NIR	NDVI
Replication I (R_1)				
T_1	Absolute control (water spray)	6.22	28.46	0.64
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	6.99	37.63	0.68
T_3	GI Chitosan @ 1 ml/lit	6.84	33.57	0.66
T_4	Potassium salt of active phosphorus @ 4 g/lit	6.12	39.79	0.73
T_5	T_2 and T_3 alternatively	6.05	33.15	0.69
T_6	T_2 and T_4 alternatively	6.97	42.88	0.72
T_7	T_2, T_3 and T_4 alternatively	4.77	37.60	0.77
Replication II (R_2)				
T_1	Absolute control (water spray)	10.62	36.12	0.54
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	7.82	34.98	0.63
T_3	GI Chitosan @ 1 ml/lit	9.87	40.50	0.60
T_4	Potassium salt of active phosphorus @ 4 g/lit	6.76	40.26	0.71
T_5	T_2 and T_3 alternatively	6.34	32.48	0.67
T_6	T_2 and T_4 alternatively	6.12	35.26	0.70
T_7	T_2, T_3 and T_4 alternatively	6.06	42.40	0.74
Replication III (R_3)				
T_1	Absolute control (water spray)	11.86	54.77	0.64
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	9.83	53.55	0.68
T_3	GI Chitosan @ 1 ml/lit	5.14	26.21	0.67
T_4	Potassium salt of active phosphorus @ 4 g/lit	6.48	39.50	0.71
T_5	T_2 and T_3 alternatively	6.04	32.99	0.69
T_6	T_2 and T_4 alternatively	5.56	33.92	0.71
T_7	T_2, T_3 and T_4 alternatively	5.45	35.99	0.73
RED = Red light, NIR= Near-infrared and NDVI= Normal difference vegetation index				

Table 2.1: NDVI mean after second spray using spectroradiometer

Tr. No.	Treatment details	NDVI mean
T_1	Absolute control (water spray)	0.60 (4.47)*
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	0.67 (4.69)
T_3	GI Chitosan @ 1 ml/lit	0.64 (4.60)
T_4	Potassium salt of active phosphorus @ 4 g/lit	0.72 (4.88)
T_5	T_2 and T_3 alternatively	0.68 (4.74)
T_6	T_2 and T_4 alternatively	0.71 (4.84)
T_7	T_2, T_3 and T_4 alternatively	0.74 (4.95)
S. E. (m) ±		0.013
C.D. at 5%		0.041
NDVI= Normal Difference Vegetation Index, * Values in parentheses are arc sin transformed		

3.3. NDVI after the third spray using spectroradiometer

Table 3 indicates the NDVI obtained after the third spray using spectroradiometer. In replication first (R_1) the treatment T_7 (T_2, T_3, and T_4 alternatively) showed the highest NDVI as 0.63. This was followed by T_4 (Potassium salt of active phosphorus @ 4 g/lit) and T_6 (T_2 and T_4 alternatively) as 0.60, T_5 (T_2 and T_3 alternatively) as 0.57, T_2 (Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit) as 0.52, T_3 (GI Chitosan @ 1 ml/lit)as 0.47. The lowest NDVI obtained in treatment T_1 absolute control (water spray) as 0.38. All attempted disease management treatments (T_2 to T_6) were significantly superior over T_1 (absolute control: water spray).

Similar trend of values was noticed among the treatments under replications II and III.

Table 3.1 revealed the NDVI mean values obtained after third spray using spectroradiometer. The highest NDVI mean was obtained in treatment T_7 (T_2, T_3, and T_4 alternatively) as 0.64. This treatment was statistically superior over rest of all the treatments. This was followed by T_4 (Potassium salt of active phosphorus @ 4 g/lit) as 0.61, T_6 (T_2 and T_4 alternatively as 0.57, T_5 (T_2 and T_3 alternatively) as 0.55, T_2 (Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit) as 0.52, T_3 (GI Chitosan @ 1 ml/lit as 0.49. The minimum NDVI mean was noticed under treatment T_1 (absolute control: water spray) as 0.41. All attempted disease management treatments (T_2 to T_6) were significantly superior over T_1 (absolute control: water spray).

Table 3: Replication wise NDVI after third spray using spectroradiometer

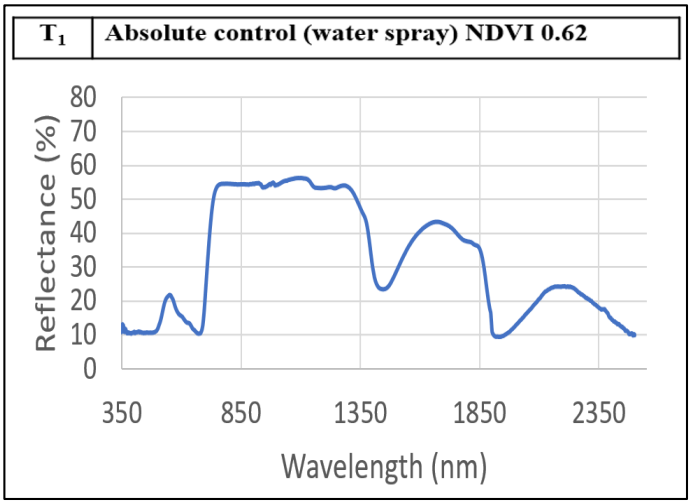
Treatment details		RED	NIR	NDVI
Replication I (R_1)				
T_1	Absolute control (water spray)	25.67	57.17	0.38
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	16.95	53.90	0.52
T_3	GI Chitosan @ 1 ml/lit	15.39	43.43	0.47
T_4	Potassium salt of active phosphorus @ 4 g/lit	13.76	55.72	0.60
T_5	T_2 and T_3 alternatively	14.88	55.71	0.57
T_6	T_2 and T_4 alternatively	13.69	55.11	0.60
T_7	T_2, T_3 and T_4 alternatively	11.78	52.36	0.63
Replication II (R_2)				
T_1	Absolute control (water spray)	14.96	53.61	0.56
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	12.37	53.48	0.62
T_3	GI Chitosan @ 1 ml/lit	13.74	51.76	0.58
T_4	Potassium salt of active phosphorus @ 4 g/lit	10.34	51.92	0.66
T_5	T_2 and T_3 alternatively	12.37	55.75	0.63
T_6	T_2 and T_4 alternatively	11.69	52.97	0.63
T_7	T_2, T_3 and T_4 alternatively	9.78	51.38	0.67
Replication III (R_3)				
T_1	Absolute control (water spray)	36.24	68.55	0.30
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	23.72	59.68	0.43
T_3	GI Chitosan @ 1 ml/lit	23.18	57.45	0.42
T_4	Potassium salt of active phosphorus @ 4 g/lit	14.95	57.19	0.58
T_5	T_2 and T_3 alternatively	22.01	57.63	0.44
T_6	T_2 and T_4 alternatively	20.80	58.86	0.47
T_7	T_2, T_3 and T_4 alternatively	12.67	55.54	0.62
RED = Red light, NIR= Near-infrared and NDVI= Normal difference vegetation index				

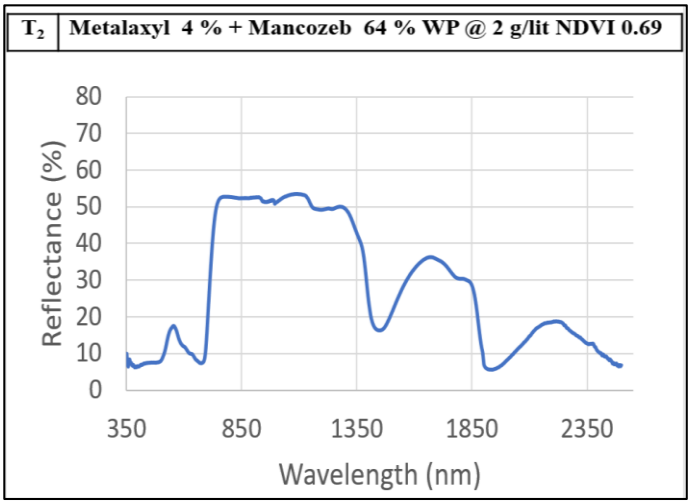
Table 3.1: NDVI mean after third spray using spectroradiometer

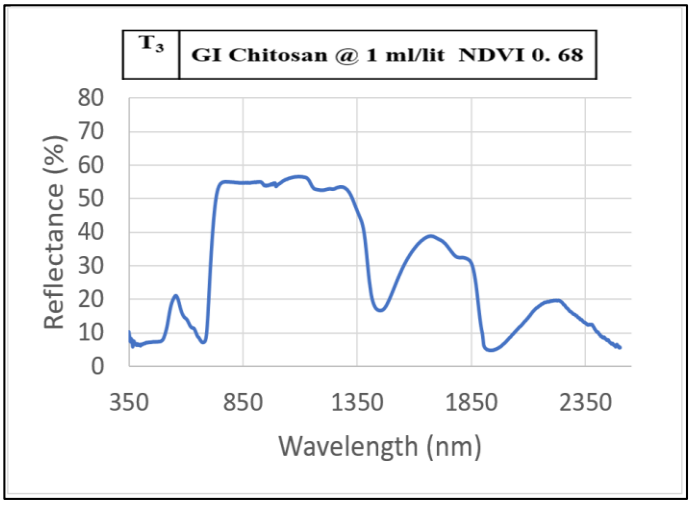
Tr. No.	Treatment details	NDVI mean
T_1	Absolute control (water spray)	0.41 (3.67)*
T_2	Metalaxyl 4% + Mancozeb 64% WP @ 2 g/lit	0.52 (4.14)
T_3	GI Chitosan @ 1 ml/lit	0.49 (4.01)
T_4	Potassium salt of active phosphorus @ 4 g/lit	0.61 (4.50)
T_5	T_2 and T_3 alternatively	0.55 (4.25)
T_6	T_2 and T_4 alternatively	0.57 (4.32)
T_7	T_2, T_3 and T_4 alternatively	0.64 (4.60)
S. E. (m) ±		0.023

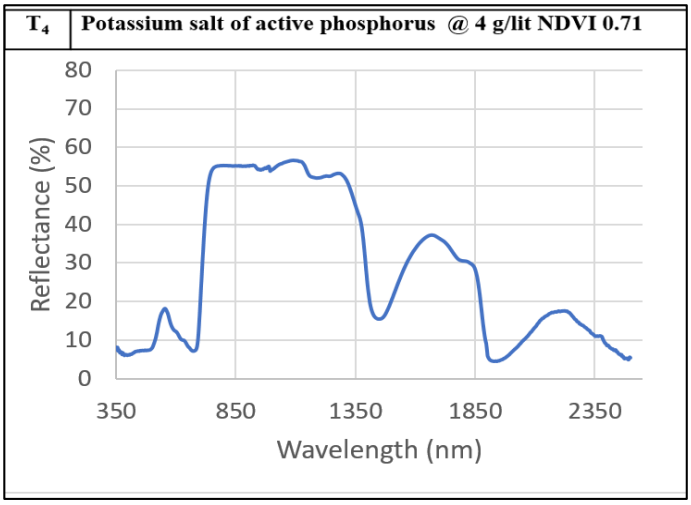
C.D. at 5%	0.072
NDVI= Normal Difference Vegetation Index, * Values in parentheses are arc sin transformed	

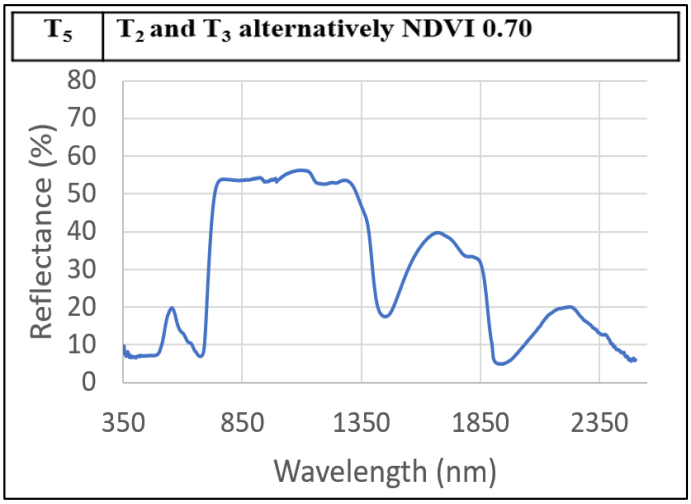
Results obtained in an application of spectroradiometer infrastructure in the study of downy mildew of bitter gourd caused by *pseudoperonospora cubensis* have appeared similar findings with earlier workers *viz* Bravo *et al.* (2003) [1], studied hyperspectral imaging, the spectral signature of tissue colonized by a pathogen, and compared it to the spectral signature of healthy tissue and plant canopies. Thenceforward, Xu (2007) [4], studied the reflectance spectra of tomato leaves and determined the most effective wavelengths for characterizing the plant diseases caused by pests. Due to both the visible images and spectral images for detecting the crop's diseases having some limitations, the precision and stability of the test results are affected inevitably. After that, Chen *et al.* (2008) [2], used hyperspectral measurement to identify cotton infected by verticillium wilt. Following this, Zhang *et al.* (2008) [7], proposed one hyperspectral microscope image pre-processing framework for FHB-infected kernel extraction. From that day Nansen *et al.* (2009) [6], used in-field spectral images for the early detection of yellow rust in wheat. Following this, Youwen Tian and Lin Zhang (2012) [5], used hyperspectral imaging technology, which can integrate the advantages of spectral detection and image detection, meets the need of detecting the cucumber diseases fast and nondestructively.

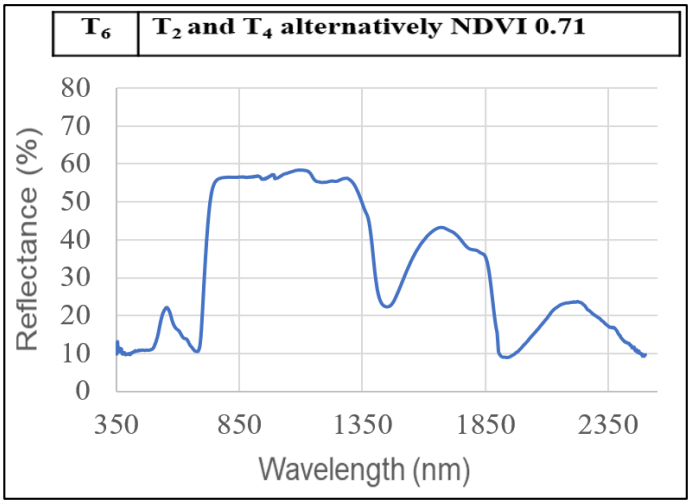


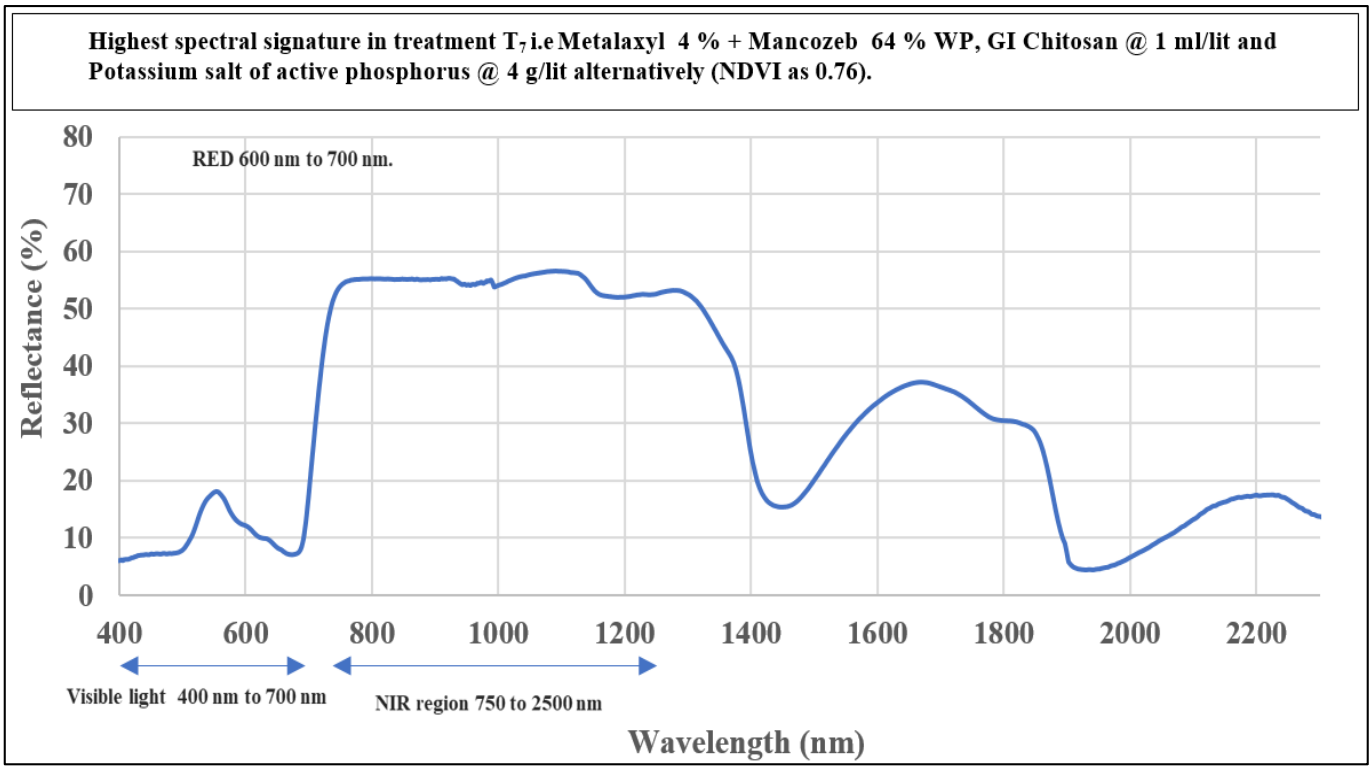












All graphs showing spectral signatures after first spray in replication I (R_1) using spectroradiometer

Conclusion

The highest NDVI mean was obtained in treatment T_7 (T_2, T_3, and T_4 alternatively) as 0.76. This treatment was statistically superior over rest of all the treatments. The minimum NDVI mean was noticed under treatment T_1 (absolute control: water spray) as 0.64. Thus, alternative use of Metalaxyl 4% + Mancozeb 64% WP, GI Chitosan @ 1 ml/lit and Potassium salt of active phosphorus @ 4 g/lit for management of downy mildew disease in bitter gourd having more normal difference vegetation index than the other fungicidal sprays in field. Overall present research on construction of disease symptom image library through hyperspectral technique showed that the spraying of Metalaxyl 4% + Mancozeb 64% WP, GI Chitosan @ 1 ml/lit and Potassium salt of active phosphorus @ 4 g/lit in an alternative form have synergetic effect on disease incidence and were effective than treated alone.

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